

Variations in Development and Motor Control in Goiterous and Non-goiterous Adolescent Girls

BY
LOUISE A. NELSON

A DISSERTATION

Submitted to the Board of University
Studies of the Johns Hopkins University
in Conformity with the Requirements for
the Degree of Doctor of Philosophy,
June, 1926

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VARIATIONS IN DEVELOPMENT AND
MOTOR CONTROL IN GOITEROUS
AND NON-GOITEROUS
ADOLESCENT
GIRLS

PLAYGROUND-ATHLETIC LEAGUE, Inc.

Study No. 2.

May, 1929.

Doctor Nelson's study represents a type of investigation that is being encouraged in Maryland by the Playground-Athletic League, Inc. It appears that such material, in its final form, should be available not only to those professionally concerned with the mental hygiene and physical development of young people, but that it should also be accessible to such laymen as support, either with their time or their contributions, the activities of agencies that cooperate with the schools in working for the physical well-being of pupils. To serve this purpose, the Playground-Athletic League, Inc., of Maryland, will from time to time issue in book or bulletin form material produced under its supervision that seems of more than purely local interest. The present paper is the second number in this series.

BALTIMORE, MD.

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Variations in Development and Motor Control in Goiterous and Non-goiterous Adolescent Girls

CHAPTER I

STATEMENT OF THE PROBLEM

Growth and movement are characteristics of all normal human organisms. Both are qualitative and both are quantitative; both are conditioned by inherent, as well as internal and external environmental factors. In growth or development the quantitative aspect is closely associated with the metabolism of the body which in turn is largely regulated by the functional activity of the thyroid gland.

Adolescence, a period during which the functional activity of the thyroid gland is accelerated, is a period, concerning which, as one writer has said, the outstanding fact is, "that we know that we know nothing about it." It is a period, not of constancy, but of change. Development is being speeded up and new functions are appearing, but nothing of a definite nature is known regarding the inter-relation of the speed and equilibrium of the processes taking place, the proper regulation of which results in a normally developed and normally controlled

adult. The available data for both the lower mammals and man show wide variations in the age of onset of puberty, in the neuro-muscular balance, and in the anthropometric measurements of individuals of equal chronological age.

The problem involved in this study is an attempt to determine in what respect goiterous adolescent girls differ from non-goiterous adolescent girls, with regard to neuro-muscular control and anthropometric measurements, when goiter is defined exclusively in terms of size of thyroid enlargement.

The investigation was undertaken for the Playground Athletic League of Baltimore for the following reasons: (1) Their examining physicians had found that, in some of the high schools throughout the state of Maryland, and especially in the Allegany County schools, as high as 75 per cent of the girls examined had thyroid enlargement, of one degree or another, and that a few individuals, in whom the enlargement was so slight as to escape casual observation, showed the nervous and mental symptoms which characterize thyrotoxic conditions, namely exaggerated emotionality, great irritability, restlessness, instability, vaso-motor disturbances, quick fatigability, and tremor. Two of these individuals, however, were superior students, one being by far the best student in her class; the other, while superior in class work, was so unstable emotionally that she was considered peculiar by her principal and teachers. Another, the youngest child in her class and with the best scholarship record in the school which she attended, showed no emotional instability, no lack of motor control, no conduct disorders; yet she had a very marked thyroid enlargement. (2) It seemed desirable to try to determine whether the lack of precision and lack of well coördinated movements found, to so marked a degree,

in many individuals showing pronounced degrees of hypo- and hyper-secretion of the thyroid, were also to be found in any degree in these goiterous adolescent girls; also to determine whether these girls varied in development, as measured by height and weight, to a marked degree, from the average normal standards and whether the onset of menstruation and of thyroid enlargement were correlated.

The experimental work covered a period of ten months, divided as follows: February 1, 1924 to June 20, 1924 and September 1, 1924 to January 31, 1925.

CHAPTER II

HISTORICAL

1. INTRODUCTION

The physiological and psychological aspects of hyper- and hypo-thyroidism are distinct and readily recognizable, and these together with the chemical aspect form an integrated whole in the organism and present one of the most complex, if not the most complex, problems in all physiology and psychology. The definite dependence of normal physical and mental development and functioning, on the proper functioning of the thyroid is clearly reflected in the cretin, with his retarded growth, low mentality, and usually small size skull cavity and exaggerated reflexes. That tremendous changes take place in the emotional and mental life of the individual when exophthalmia and hyper-thyroidism exist are matters of general knowledge.

A review of the literature of goiter dating, as it does, from 2000 B.C. to the present day, is entirely outside the scope of this study, but a brief mention of a few facts relevant to the work presented seems pertinent, in order to explain the subsequent division of the paper and the classification of the material.

Enlargement of the thyroid, or goiter is, probably as old as the human race, yet its primary cause continues to remain unknown. The best conception of the etiology of simple goiter, at present, is that it is a "compensatory or work hyperplasia immediately dependent on a relative or an absolute deficiency of iodine. Whether the defi-

ciency in iodine is primary or secondary cannot be stated."

The dawn of scientific knowledge of the function of the thyroid begins with the work of Santorini (1724), who found that the thyroid gland had no duct, and who thought that the gland might be forced to expel its secretion by a contraction of an over-lying muscle. Since then the thyroid has been classified as a gland without a duct, which secretes a special fluid that is received into the veins and so introduced into the general circulation of the blood and lymph.

Definite knowledge of the function of the thyroid dates from 1873 when Sir William Gull published his clinical-pathology study, "On a Cretinoid State supervening in Adult Life in Women." His observations were first experimentally confirmed in 1882 by the Brothers Reverdin and in 1883 by T. Kocher in operations for total thyroidectomy in man. Some of these human subjects, after the operation, developed parathyroid tetany and died, others within from thirty to sixty days developed a state akin to that described by Gull (myxedema).

In 1895 Bauman reported iodine as the normal constituent of the thyroid and later work established the fact that the thyroid exercises its influence on metabolism by means of the stable iodine-containing hormone isolated by Kendall in 1916 in crystalline form and called thyroxine.

And now the major functions of the thyroid are known to be those of providing a means through this iodine and CNOH containing hormone for: (1) causing differentiation and growth in early life and (2) through the CNOH radical, for maintaining a higher rate of metabolism than would otherwise exist, and for varying this rate. This functional activity is, according to Marine, controlled chemically, through the blood stream and perhaps also indirectly through the sympathetic nervous system.

That functional activity is accelerated during adolescence and that enlargement of the gland or goiter of one degree or another frequently appears is a matter of common knowledge. A general agreement as to the changes which take place in the formation of these goiters seems to exist, although agreement is not universal as to the factors which initiate these changes.

The increased functional activity is associated with a diminution of the iodine supply of the gland. When this falls below a certain level (0.1 per cent), thyroid enlargement begins. Then after a period of activity, the gland usually reverts to a colloid or resting state and the function of the gland again becomes more or less normal. This does not mean that the enlargement disappears. The increase in size is regarded as a compensatory mechanism and represents an adaptation on the part of the organism. In interpreting the thyroid change in goiter, Marine (1922) says:

“One must bear in mind the simple thyroid cycle which, beginning with the normal cell, consists of progressive changes through all degrees of hypertrophy and hyperplasia and regressive changes either (1) throughout all degrees of atrophy, or (2) throughout all degrees of involution to the resting colloid or nearest normal state that such thyroids can again assume which have once undergone hyperplasia.”

There seems to be a consensus of opinion that the majority of goiters which develop in adolescence are of the colloid variety and usually represent a hypo-functioning of the gland. Different degrees of hyper- and hypo-function are, however, evidenced by clinical manifestations and this type cannot be said to always denote a hypo-function though it usually does. The adenomatous goiter found in adolescence, in contrast to the colloid type, implies that there is a fundamental cell

multiplication which is apt to be attended by a hyper-function of the gland. Hyper-activity may exist, however, even to a toxic degree without the slightest observable or palpable enlargement of the gland. Considered collectively, adolescent goiters are thought of, by many, as goiters which appear at the adolescent period of life and disappear when development is completed, and are designated as a purely physiological state. There is some clinical, but no experimental evidence to support this view. Marine is an exponent of the above view. Hertzler and many others, on the other hand, maintain that there is no such thing as "simple physiological goiter."

Because of the close association of the advent of the menstrual cycle with adolescent goiter, a relationship has been assumed to exist between the thyroid and the ovaries. There is no evidence to substantiate this assumption. Abnormalities of menstruation have been frequently described in thyroid disorders and it is usually stated that both myxedema and exophthalmic goiter may be accompanied by either menorrhagia or amenorrhea. Save for the clinical observations of Gardner-Hill and co-workers (1925) on the menstrual rhythm in adolescent goiter there is no information for adolescent girls.

During the past decade investigations have been carried on which have demonstrated a very definite relationship to exist between the thyroid function and growth of the central nervous system as represented by the brain and the spinal cord. And that the neuromuscular system is involved in states of both hypo- and hyper-function of the gland has been shown both clinically and experimentally. Also during the past seven or eight decades clinical observations on man and extirpation experiments on animals have established the fact that deficient thyroid secretion results in a marked

retardation of body growth, while thyroid feeding and transplantation result in acceleration of growth, especially when administered before and during puberty. That this growth is due to a secretion of the gland specifically stimulative to growth has yet to be substantiated. The present evidence is that the retardation or acceleration due to thyroid deficiency or excess is a consequence of altered metabolism.

2. RELATION OF THE THYROID GLAND TO GROWTH AND DEVELOPMENT

Although it remains to be proved that a specific secretion of the thyroid gland is specifically stimulative to growth, nevertheless, the importance of the role of this gland in the process of growth and development has been very generally established of recent years. Absence or diminution of function of the gland, at an early age, leads to inhibition of growth; increase is thought to lead to a slight acceleration. The accumulation and repartition of fat in the body is regulated by the thyroid. It is well known that in hypo-thyroidism adipose tissue is increased, whereas in hyper-thyroidism it is diminished. Puberty is considerably retarded and menstruation remains absent in athyroidism and cretinism. The most important contributions up to 1926 to the evidence of this for lower organisms, and for man, are cited below.

a. Relation to Infra-human Organisms.—Schiff (1884), stimulated by the observations of Kocher and Reverdin, repeated his own experiments of 1856, 1857, and 1858 and noted among other symptoms, following a loss of thyroid secretion, in dogs, rats, and rabbits a general arrest of growth. Hofmeister (1892) found that the extirpation of the thyroid of young rabbits was followed by a retardation of growth, and the development of a

condition of chronic cachexia. By further experiments in 1894-6, he showed that the arrest of growth was due to a remarkable retardation of the process of ossification, both of the epiphyses and of the synchondroses. The long bones, the pelvis and the vertebral columns showed the greatest departure from the normal, the skull the least. The growth of the long bones was retarded to the extent of at least a third of their proper length. Moussu (1892-3) noted that removal of the thyroid of young animals retarded development generally. In 1895 von Eiselberg found that in sheep whose thyroids had been removed, at the age of ten days, there was conspicuous retardation of growth. Magnus-Levy reported, in 1895, that feeding thyroid caused a loss in weight in animals. Akopenko (1898) and Steinlein (1899) showed that the growth of the skeleton, particularly the long bones, was disturbed along with that of the body as a whole when the thyroid gland had been removed. Smaller bones were found in the smaller thyroidless animals. Moussu (1899) reported that small doses of thyroid stimulate the rate of growth in young dogs, but that large doses are toxic.

Bircher (1910a) (1910b) fed thyroid to young rats and found a retardation in growth and body weight, but an acceleration in the process of ossification.

Hoskins (1910b) reports that with thyroid-fed pregnant guinea pigs many abortions and several still-born occurred. The newborn (apparently normal) young of the treated mothers weighed on the average of 12 grams less than the controls.

Pick and Pineles (1910) reported their results on the activity of various laboratory preparations in experimental cretinism in young goats. With the desiccated thyroid there was a rapid improvement. A thyroidin preparation was negative in activity. On the other hand,

earlier investigators (Bauman, Ewald, Lichtenstern, Magnus-Levy) claim that thyroïdin is just as active in removing the symptoms of thyroid deficiency as the desiccated thyroid. Pick and Pineles found that symptoms of cretinism can be controlled by feeding thyreo-globulin. Oswald and Magnus-Levy also found thyreo-globulin to be active.

Kendall (1912 and 1915) reported results on certain split products of the thyroid gland which he calls "Extract A" and "Extract B." The former affects the nitrogen metabolism, body weight and temperature. It causes marked tachycardia, nervousness and tremor. The latter shows no toxicity. The skin and hair become entirely normal in human cretins. The weakness of bones, muscles and joints soon disappear.

Carlson, Rooks and McKie (1912), and Ferrant (1913) fed thyroid to birds and mammals. They concluded that large doses of thyroid are toxic. In the thyroid-fed rabbits of Ferrant the heart, liver and pancreas showed degenerative changes.

Schäfer (1912) fed thyroid to young white rats, noting an increased food consumption, increased metabolism, and acceleration of growth. Fordyce (1912) on the other hand observed a decrease in rate of growth in white rats fed on thyroid.

Gudernatsch (1912-14) found that thyroid administered to a large number of tadpoles retarded growth (i.e., a toxic effect) but hastened metamorphosis of the limbs and tail. Lenhart (1915) reached the same conclusion. Cotronei (1914), West (1914), Morse (1915), Abderhalden (1915), Romeis (1915) and others have confirmed in general the results of Gudernatsch.

Iscovesco (1913) used a preparation of thyroid extract which he injected daily into young rabbits and reported a marked acceleration of growth with young animals

(initial age 45 days), and a slight increase in growth rate with older animals (initial age $4\frac{1}{2}$ months). He found nearly 100 per cent hypertrophy measured in grams per kg. of body weight.

Hewitt (1914) fed thyroid gland to white rats noting a loss in weight. In 1920 he claims to have obtained a decrease in growth rate in young rats. He gives no observations on controls.

Hoskins (1916) found that thyroid feeding, in sub-toxic doses causes little or no change in body weight in growing rats. There is possibly a slight stimulation in growth of the body as a whole, balanced by a decrease in the amount of free fat in the body.

Basinger (1916) reports that transfusion of hyperthyroid blood serum into cretin rabbits is effective in increasing growth and in controlling other symptoms of cretinism, but that the improvement is not so marked as with thyroid feeding. Standard thyroid preparations, when given in carefully controlled non-toxic doses, will increase the growth of cretin rabbits and prevent development of, or counteract, the other symptoms of cretinism, but discontinuing the thyroid feeding leads to a return of some of the cretin symptoms. Cretins are more susceptible than normal animals to the toxic action of thyroid.

Herring (1917b) compared thyroid fed and control white rats from the same litter and of the same sex. Fresh ox thyroid (0.1 to 0.2 gm.) was fed daily. A slight decrease was observed in the rate of growth of male rats. More variable results were obtained with the females. They appeared to be more susceptible to the treatment, but the average gain in weight differed very little from that of the controls.

Palmer (1917) found that extirpation of the main thyroid gland in young pigs did not induce cretinism, at

least within a period of one year, but caused a set retardation of growth.

Terry (1917-8) and Hoskins (1923) confirmed the findings of Alkopenko, Hofmeister and v. Eiselberg. Hoskins used white rats. His results, based on average figures for a number of rats, do not show definite effects of thyroid feeding on the rate of growth; the growth curves are approximately the same as those from the average figures for a series of controls from the same litter. He points out that the normal growth of the albino rat shows material variation, not only in different strains and under different conditions of environment, but even among litters when all conditions are kept as nearly constant as possible, so that in all such tests experimental and control animals should be selected of the same sex and from the same litter. He used both fresh and recently desiccated gland without any noticeable difference in result. The dose given every second day, varied from 10 mg. of desiccated (or 40 mg. of fresh) to 200 mg. of desiccated calf thyroid gland in different experiments.

Cameron and Carmichael (1920-1) found that continued small doses of desiccated thyroid gland fed to young white rats produced (a) a definite and invariable decrease in growth rate; (b) hypertrophy of the organs concerned with increased metabolism—heart, liver, kidneys, adrenals, etc. (confirmatory of Hoskins and Herring); (c) disappearance of fat (confirmatory of Hoskins and Herring). The decrease in rate of growth was proportional to (a) the amount of thyroid fed and (b) the iodine content of the thyroid fed. These investigators took the precaution to use control animals from the same litter, and always based the dosage on the weight of the animal at the time of treatment. Their dose was relatively small compared with that used by all

previous experimenters. In 1921-22 Cameron and Sedziak repeated the first of these experiments with confirmatory results.

In 1923-25 Hammett made a series of experiments on albino rats of both sexes, adequately controlled as to age, sex, litter, diet, etc., during the growth period. The test animals were deprived of the thyroid apparatus (thyroid plus parathyroids) when 75 to 100 days of age. He reports that lack of thyroid secretion causes a marked retardation of absolute growth in weight and length, a desiccation, a decrease in ossification, and retardation of anatomical differentiation. Weight and length are retarded in both sexes and more in the female than in the male, the degree of inhibition being less in the rats thyroidectomized at 100 days. Various organs differ in the degree of their response to the thyroid deficiency. There is a differential effect exerted upon body length, body weight and tail length; also there are distinct qualitative and quantitative differences in the response of the humerus and the radius to the lack of thyroid and parathyroid secretions in sexually mature albino rats.

In the experiments cited above it will be noted that there is considerable disparity of results. These differences are probably largely due to four factors: (1) a failure to consider the correlation of the thyroid gland with the organs of metabolism and other organs of internal secretion; (2) a failure, as Cameron and Carmichael have pointed out, to compare every experimental animal with a control animal from the same litter kept rigidly under the same conditions; (3) a failure to use a variable dosage in feeding experiments, for it seems reasonable to infer that a fixed dose given over a long period to an animal of constantly changing weight and to a series of animals of different initial weights would not produce comparable effects; and (4) a failure to consider

the inherent stock difference of the animals used. However, this very disparity of results has been valuable in that it has served as a stimulus to further and more careful experimentation and has emphasized the meagerness of definite knowledge in this part of the field.

b. Relation to Man.—Uhlenhuth says: "It is probable that the development of the individual is controlled by the thyroid hormone." And since in cretins the thyroid functions imperfectly or not at all, the difference between the development of a normal individual and that of a cretin may be assumed to indicate the scope of the control of the thyroid hormone. Growth in the cretin is slowed up almost to cessation, ossification of the skeleton is inhibited, in consequence of which the epiphyses of the long bones remain separated; disturbances occur in the development of the teeth and an infantile condition of the sex organs persists. The same conditions result from a loss of the thyroid hormone in early life, and the trophic disturbances of the osseous system after total thyroidectomy are in direct proportion with the age at which the loss of the thyroid function occurs; the younger the individual the more intense the disturbance seems to be.

Cretinism as a result of thyroid insufficiency was first noted by Paracelsus in the early part of the seventeenth century, and remained the only result of thyroid insufficiency known before Gull (1873) published his paper on myxedema. In 1874 he described five cases of myxedema in women, but until the publications of both Reverdin and Kocher in 1882-83, the clinical conditions which follow suppression of the thyroid hormone were neither known nor appreciated. In 1887 Dr. Savill called attention to the fact that the condition—myxedema—is common to both sexes. The 1891 Murray showed that myxedema could be prevented by subcutaneous injection

of thyroid extract and in 1892 Sir H. MacKenzie of London and Howitz of Copenhagen demonstrated the efficiency of oral administration of dried thyroid gland in myxedema.

In 1895 Magnus-Levy determined the metabolism of adults with exophthalmic goiter and found that it was increased, while in patients with cretinism or myxedema it was much diminished.

In 1900 Vassale and Generali demonstrated that the aqueous extract of the desiccated, or raw thyroid, when injected intravenously, was able to neutralize the effects of thyroidectomy.

Kassowitz, in 1899-1906, published tables on growth in height of myxedematous children showing that of the children examined those of $2\frac{1}{2}$ years were 9.8 per cent below the height of normal children of the same age; children of $4\frac{3}{4}$ years, $5\frac{1}{4}$ years, $7\frac{1}{2}$ years, $10\frac{1}{2}$ years and 12 years he found to be 17.8, 18.8, 27.2, 29.6, and 30.1 per cent respectively, under the standard height for age.

The most important observations on the effects of thyroid feeding in cretinism follow: In 1907 von Eyselt reported an increase in the stature of cretins of 20 to 33 years of from 6.5. to 22.5 cm. to whom thyroid has been administered. The same writer reports increased growth in from 52 to 59 cases of cretinism treated for from one to three years.

In 1914 von Jauregg stated that out of fifty-one cretins to whom thyroid was administered for from 3 to 6 years 49 increased in stature above the normal average for the corresponding age and intervals; in 23 out of fifty-one cases growth ranged from 10 to 15.5 cm. during one year of treatment, one subject, 27 years old, growing 4 cm., another 23 years, 12.5 cm., while a third, a girl of 19 years, increased her height from 107

to 135 cm., and a fourth, under treatment from his fifteenth to his twenty-second year, increased his stature from 105 to 160 cm. (from 42 to 64 inches). Christoffer-sen reports a patient of 45 years who grew 5 cm. The rate of growth (in these individuals) was greatest during the first year of treatment and after that gradually approached the normal.

Increased growth in 85.7 per cent of 440 cases under treatment for from one to two and one-half years is reported by Kutscher. Among these were subjects aged 25 and 26 years, who grew 3 cm. and 7.5 cm. respectively. Osler and others have published large series with similar results.

Fleming (1922) reported detailed observations on two cretins, one aged 23 months and the other 4 years and 8 months, before and during treatment. He confirmed the earlier observations that the basal metabolism of the untreated cretin is much below normal, and obtained an increase in the metabolism by the administration of thyroid extract. He showed conclusively that the omission of thyroid therapy resulted in a fall in the basal metabolism toward its previously low level, with a subsequent rise shortly after treatment was resumed.

Talbot (1923) found that by giving cretins doses of thyroid sufficient to bring their basal metabolism up to the expected basal metabolism for age and keeping it there, the actual curve of growth approximated the expected curve. McGraw (1924) reported marked improvement in growth in 4 cases of cretinism, on thyroid extract. This growth was never so marked as when anterior lobe of pituitary was combined with the thyroid treatment. Symptoms of cretinism returned when the treatment was discontinued.

Evidence that thyroid excess effects growth in humans is not available. A relationship is assumed to exist

between thyroid activity and the production of micro-splanchnic and macrosplanchnic body types, the former being thought to be associated with greater thyroid activity. The literature affords a few suggestive clinical studies, such as that of Holmgren (1910) who observed that, in 89 cases of exophthalmic goiter occurring before the age of 14 years, there was an unusual growth in long bones, with early ossification. He emphasizes the contrast of this increased growth in young exophthalmic persons with the dwarfism of cretinism and assigns it to a hyper-function of the thyroid gland. In a later paper he reported 127 cases of hyper-thyroidism in youthful patients with an increase in length of body in 75 per cent.

In a study (1925) of 100 goiterous adolescent girls made by Gardner-Hill and co-workers, the majority of the subjects were found to be overgrown when compared with the Holt norms for height.

3. THE RELATION OF THYROID ACTIVITY TO THE CENTRAL NERVOUS SYSTEM

Data on the relation of thyroid function to the central nervous system are scarce and such as do exist are, with a few exceptions, unsatisfactory. Previous to 1923 the relation of the growth of the central nervous system to thyroid function had received no clear-cut scientific experimental proof.

The early experiments were fragmentary and unsatisfactory. Varying results were obtained; only a few animals were used, and these could not be kept alive long enough for changes to be accurately measured. Descriptions of methods were inadequate. Further, no distinction was made between the function of the parathyroids as separate from that of the thyroid until 1891 when Gley rediscovered the former glands. However, a generalized evidence accumulated which shows

that a deficiency or absence of thyroid function adversely affects brain and cord growth. The most important contributions to this evidence are cited below.

In 1844 Bardeleben found that extirpation of the thyroid gland had little effect on dogs and rabbits. The Brothers Reverdin in 1882 and Kocher in 1883 showed that complete removal of the thyroid from humans caused cretinism; Combe and others reported similar observations. Schiff (1884) repeated his own experiments of 1859 and found that no serious results followed thyroidectomy in rats and rabbits. In the dog and the cat death ensued. The symptoms noted were defects in locomotion, alterations in sensibility, vaso-motor irregularities, and general malaise. In the same year (1884), Wagner, the Italian experimenters Sanquirico and Conalis, and Colzi all confirmed these results. Horsley (1885) showed the same for monkeys. Five days after the operation his animals exhibited a slight fibrillar tremor in the muscles of the face, hands and feet, became dull, listless and subjects to outbursts of rage. Halsted (reported by Welch) (1888) confirmed Schiff's results, as did also Fuhr in 1886 and 1889, Ewald in 1887 and 1889, and von Eiselberg in 1893-4. Akopenko (1898) removed the thyroid from cats and rabbits and found that these animals lived from two to three weeks, but that their skulls were smaller and that the brain and cord weighed less than those of the unoperated controls.

Drobnick and Philipeaux (1884) and Munk (1887) found that animals could survive the removal of the thyroid and concluded that the results of the other investigators were due to an injury of the nerves and reflex centers instead of the loss of the thyroid. Gley in his experiments made between 1892 and 1911 cleared up this confusion, when he found that the entire removal of the thyroid-parathyroid apparatus was almost invari-

ably followed by death, whereas removal of the thyroid alone was not fatal. His results were confirmed by Vassali and Generali in 1894 and 1900. And in 1904 and 1906 Jolly and Vincent found that loss of the parathyroids, even when the thyroid was left intact, was followed by death. Allen (1918) showed that in thyroidless tadpoles brain growth does not proceed to maturity. These tadpoles never became frogs.

Clinically, the observations made on the retarded mental growth of cretins points to failure of growth of the brain in man when thyroid deficiency exists. From the clinical reports on this lack of psychic development in cretins the generally accepted theory of thyroid deficiency as a contributory cause of cretinism has grown up. This theory finds its support largely in two facts; (1) that thyroid disturbance is prevalent in regions where cretinism exists, and (2) that post mortem examinations of cretins show either a very small and structurally abnormal gland or an entire absence of this gland.

Quoting from Janney (1922): "The central nervous system suffers severely" in cretinism. "The brain may show defective convolutions, and all parts of the central, peripheral and autonomic nervous systems exhibit the signs of retarded and deficient development." Many of the stunting effects of cretinism are probably secondary.

Quoting from Hammett: "If the mental development of the cretin is compared with the bodily or physiological development, the impression is given that the brain development has lagged behind the physiological development of the body and hence of the spinal cord." That this is true Hammett's own experiments seem to indicate. In 1923-24 he made the first thoroughly scientific, quantitative studies demonstrating that a definite relation exists, in mammals, between thyroid deficiency and

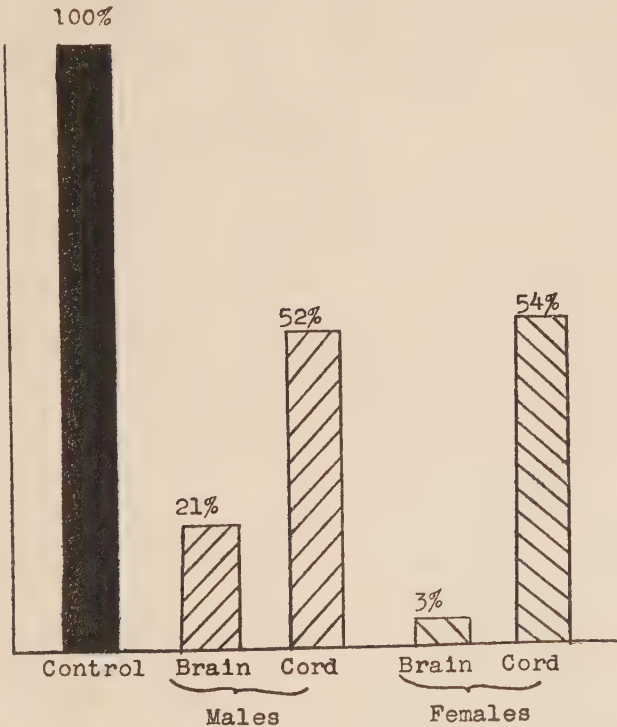
brain and cord growth. He thyroidectomized (thyroid plus parathyroids) two groups of albino rats; one group at 100 days, and the other at 75 days, and allowed the animals to grow until 150 days old. He used both sexes, adequately controlled as to litter, sex, age, diet, and environment during the growth period. At 150 days of age, when growth was complete, these rats were killed and comparative measurements and weights recorded, along with measures and weights of control groups of rats, for the body as a whole and for the various organs. A marked effect of thyroid deficiency was found in the growth of the central nervous system, as represented by the brain and spinal cord taken as separate organs. The retardation of growth was less in both sexes when the glands were removed at seventy-five days of age than when they were removed when the rats were 100 days old. The changes due to lack of thyroid function were both quantitative and qualitative.

Figure I shows the relative changes in the brain and cord of the groups of animals thyroidectomized at 100 days.

"The solid black column of the figure represents the growth in controls as 100 per cent. The heights of the other columns represent the degree of development of the brain and spinal cord of the male and female thyroidless rats, or the degree to which these organs failed to reach the normal level." It is evident from the ensuing chart that thyroid deficiency does not produce the same quantitative effect upon development, as measured by the weight, of the brain as it does upon the cord. In the same individual the growth of the former is far more retarded than is the growth of the cord and much more so in the female than in the male.

The spinal cord, which controls the reflex nervous activities of the organism and represents an older and

relatively less differentiated part of the nervous system than the brain, in which the higher mental functions are centered, is represented as a separate organ of the nervous system from the brain. Cretins show an almost



(From Hammett.)

FIG. 1.—Growth of brain controlled by thyroid gland.

normal development of the “cordal” nervous reactions, with a nearly complete absence of cerebral function. The experiments of Hammett point the cause of this and suggest why it should be so. Hammett says:

“The data show clearly that the spinal cord, a structure which appears in the course of phylogenetic development of the central nervous system at an earlier period than the brain (cerebral hemispheres), is inherently less modified and less dependent in its growth processes upon the functions of the later-appearing thyroid than is the brain, the phylogenetic evolution of which is later than that of the thyroid gland . . .

“The fact that the growth of the spinal cord is reduced by the lack of thyroid function shows that the normal growth of the cord is partly dependent upon a normally functioning thyroid gland. In the face of these observations, it would be foolish to assume that the addition of the thyroid gland and its function of general metabolic stimulation to the organism during the progress of phylogenetic development has not modified the character of the growth of the spinal cord, either as to rate or nature of incorporated substances. It is conceivable that the age-long processes which gave rise to the type and chemical composition of structure characteristic of the spinal cord, by their priority and experience, also gave to it a high degree of inherent stability and inherent independence of growth ability. When the later appearing thyroid stimulation was superimposed upon these inherited established characteristics, they were modified, but nevertheless retained their integrity.

“With the brain, however, it is another story. This structure developed after the thyroid function had been established as a specific function of a given organ. The growth of the brain has then been influenced from its very beginnings by thyroid activity. The chemical development of the brain was conditioned by the long-established thyroid mechanism and its reflections in the metabolism of the organism as a whole. The brain had no long period of evolution nor any growth independent

of thyroid influence. Thyroid influence has been, therefore, an integral part of the phylogenetic development of the brain. It has not been, as far as we know, an integral part of the phylogenetic development of the spinal cord in its essential characteristics, both functional and chemical. It is, therefore, evident that from the evolutionary point of view the growth of the brain should be more intimately bound up with thyroid function, and sensitive to alterations therein, than the spinal cord. This sensitivity would naturally be extended to sex and age differences in the role of the thyroid in the economy of the organism, and to which the spinal cord would be less responsive."

And: "The relatively greater retardation in the growth of the brain is in agreement with the clinical picture of cretinism in man. For in this state of athyroidism the cerebral functions are apparently less developed than are the spinal cord functions. However, a comparison between growth as determined by weight and growth as determined by function has its limitations and should be so judged.

"The marked lesser retardation of cord growth as compared with brain growth indicates that the inherent growth impulse of the cord, e.g., that ability to grow which is independent of the stimulus to general growth provided by the thyroid, is much greater than that of the brain during this interval (100 to 150 days). From this it may be inferred that the metabolic changes underlying myelinization are not as dependent upon thyroid function as are other metabolic processes."

4. THE RELATION OF THYROID FUNCTION TO MOTOR CONTROL

Inasmuch as movement and its control are subjects of interest for the psychologist, the physiologist, and the

pathologist a comparatively voluminous literature has accumulated regarding them. To give a comprehensive review of this literature would be profitless here and beside the point. For reviews and bibliographies in the psychological field the reader is referred to the works of Bryan (1892), Wells (1908), Ream (1922), and Whipple (1924). Rivers (1908) has reviewed the literature on the influence of caffeine and other drugs on fatigue, and has given a critical analysis of the experimental procedure of the older workers. Hollingsworth (1912) has reviewed the literature on the effect of caffeine on muscular contraction. Marie (1883), Dana (1892), Peterson (1894), and Sattler (1908) have reviewed the clinical and experimental works on tremor, in pathological states. L. Binet has summarized the work done during the late war to correlate diminished motor control with emotivity. Wilson's articles (1925) on motility and muscle tonus will be found stimulating.

The psychological aspect of thyroid function in relation to motor coördination has received scant consideration from the psychologist beyond speculation and clinical observation, yet that hyper-secretion of the thyroid gland increases the irritability of the entire nervous system for all stimuli whether of central or peripheral origin and lowers the threshold of the stimulus is generally accepted. The voluntary muscular system is sometimes affected by tremor and weakness, the former resembling over-stimulation and the latter a loss of nervous control. Hypo-thyroidism also produces tremor; and both extremes cause impaired coördination of movement.

There is a large amount of clinical evidence available to the effect that the voluntary movements of the skeletal muscles are neither well controlled nor well directed in deficiency or excess of thyroid secretion.

Quoting from Crotti; "As a result of continued thyroid over-stimulation, the mental, motor, and trophic nerve centers lose their coördinative and sensitive power." The same author says, "measured with the dynamometer the muscular strength shows considerable diminution." According to Janney muscular weakness is one of the earliest signs of hypo-thyroidism and, Sattler in his discussion of tremor, emphasizes the lack of coördination of movement on the part of thyrotoxic individuals. Russell, Huber, Mackenzie, Johnson, Jaboulay, and Kocher (quoted by Sattler) report cases in whom writing or handwork are impossible and especially "under the influence of psychical stimulation." Muller (quoted by Sattler) reports three cases who could, only with great difficulty, get the spoon or the glass to the mouth. Vanderhoff (quoted by Sattler) reports an individual who could not drink without spilling the contents of a glass, even when the glass was only half full. Russell, Lemke, and Milkulicx (quoted by Sattler) report individuals who let everything they took in their hands drop. Whether these choreic movements co-exist with the ordinary tremor of these individuals or whether they are an exaggeration of it is a point on which there is no definite information. The mechanism involved seems to be the same as that used in voluntary movements. And this mechanism is a neuromuscular one, consisting on the motor side, of at least two nerve units or neurones (the intercentral or pyramidal and the spinal) and the muscle.

Direct experimental evidence of the lack of motor control in thyrotoxosis is less abundant than clinical evidence. Charcôt (1856) seems to have been the first to describe the lack of coördination and the presence of tremor in thyrotoxic individuals. In 1863 he reported his clinical observations in diagrammatic form. One of

his students, P. Marie (1883), was the first to measure experimentally the rate, degree, and amplitude of tremor. Using the old Marey sphygmograph he found the oscillations to be at the rate of 8.5 to 9.5 per second, the average for eleven subjects examined being 8.5. While the rate remained constant for the individual, the amplitude varied greatly. Using an India rubber weight, one end of which was attached to a tambour supported in the hand, without being pressed by the fingers, he obtained from the same individuals only a slightly tremulous line the general direction of which was rectilinear. Comparing records obtained in goiterous (form fruste) individuals by this method with those obtained in alcoholics and persons suffering with general paralysis he found a marked difference. In the latter, the figure traced was tremulous but far from rectilinear. This difference he interprets as indicating that the tremor in the hand of goiterous persons is not due to tremor of the hand itself, but rather, is communicated to the hand from the segments of the arm. The rate of tremor as reported by Marie approaches closely the rate of enervation found normally in man as determined by Beaumis, Horsley, and Schafer. The results of these workers are of interest here for purposes of comparison.

The rhythm of muscular contraction for the muscles of the fore-arm was found by Beaumis (1876) to be 10.5 per second. Schiff showed by division of the motor nerves that tremors were probably of central origin. This was confirmed by Horsley and Schäfer (1886) who demonstrated experimentally that tremor contractions whether natural or not, are caused by impulses from the central nervous system along the motor nerves, discharged rhythmically at the rate of 10 per second. This enervation rhythm may be generated in the motor cells of the spinal cord, in the medulla, pons, or mesencephalon

while cortical cells may produce rhythmic impulses numbering from 12 to 13 per second, or even more. In the same year (1886) J. von Kries called attention to familiar voluntary movements and the number that could be made per second.

In 1888 Wolfenden and Williams investigated thyrotoxic tremor, using a special myograph. A Marey tambour was connected with an India rubber bag by a long piece of glass tubing, the hand of the subject being rested against the rubber bag. These workers report an oscillation rate of 10.8 to 11.5 per second. The number of subjects used is not reported. Dana (1892) studied twenty-six forms of nervous diseases in which tremor was present, one of the number being a case of exophthalmic goiter. He employed the Dudgeon sphygmograph and obtained a rate of 8 to 9 oscillations per second for the goiterous subject. Peterson (1894), using the Ludwig kymograph with electric connections for seconds, two Marey tambours joined by a rubber tube, and rest for the arm for which the tremor was obtained, reports an oscillation rate of 8.7 to 12 per second. Stenström (1924) obtained a photographic shadow record of tremor in forty-nine cases of exophthalmic goiter with an average rate of 2 to 20 oscillations per second. His subjects varied in age from 17-69 years. Murray observed that where goiter and exophthalmia were unilateral tremor was confined to the side of the enlargement.

The variations obtained in rate for the same conditions are doubtless due, in part, to the instrument and method used and are significant in that they suggest the need of standardization of method and apparatus. The number of subjects reported on is one, only a few, or not stated. That the majority of experimenters obtained a rate closely approximating that of the normal enervation rate

of 10 as established by Horsley is obvious from a glance at Table 1. Stenström's upper limit resembles that obtained in fatigue records and is thought by recent investigators to be more nearly correct than the lower figures. Tremors of other origins approximating this rate have never been reported. Of the tremors associated with various pathological states and over-stimulation, those characterizing alcoholism, neurasthenia, hereditary tremor, epilepsy, and general paresis have been reported by the experimenters cited as having approximately the same enervation rate, namely from 8 to 10 per second, as tremor in thyrotoxic states, as reported by the earlier workers.

TABLE 1.—SUMMARY OF EXPERIMENTAL WORK ON TREMOR IN
THYROTOXOSIS
From 1886 to 1926

Types of goiter	Observer	Date	Rate per sec. reported	Method
Exophthalmic...	Charcôt	1862	4.5- 8.0-9.5	Sphygmograph
Exophthalmic (form fruste).	P. Marie	1883	8.0- 9.5	Marie sphygmo- graph
Exophthalmic...	Wolfenden and Williams	1886	10.8-11.5	Special myography —Marey tambour connected with an India rubber bag by long glass rod
Exophthalmic...	Dana	1892	8.0- 9.0	Dudgeon sphygmo- graph
Exophthalmic...	Peterson	1894	8.7-12.0	Ludwig kymograph
Exophthalmic...	Stenström	1924-25	6.0-20.0	Electrocardio- graph
Exophthalmic...	Dutil (Duthiel)	?	8.0- 9.5	?
Exophthalmic...	Graves	?	4.8- 7.0	Sphygmograph

These experiments represent all that the literature offers in the way of quantitative experimental results on thyrotoxic tremor or lack of motor coördination in

goiterous subjects from the time of the first experimental work by P. Marie (1883) to 1926.

Measures of fatigability have not been reported. Statements, such as Crotti's, to the effect that "measured with the dynamometer the muscular strength shows considerable diminution" can be found in abundance in the literature, but there are no quantitative reports.

Experimental work in animals correlating neuro-muscular function and thyroid function has been even less abundant than on man. In 1821-22 Liddell reported a preliminary investigation of thyroidectomy in sheep. He tested twin lambs on their ability to learn a simple labyrinth and thyroidectomized the twin of each pair making the better record. As soon as stigmata of cretinism appeared in the operated lambs he again tested them with the normal twin. He found that the thyroidectomized lambs had greater difficulty in relearning a simple labyrinth than the unoperated ones. The following year (1923) he investigated the effects of the loss of thyroid function on the neuro-muscular mechanism of lambs. He reports the preliminary investigation (1923) but gives no quantitative results. Two aspects of neuro-muscular condition were observed: (1) spontaneous activity, and (2) muscular power.

(1) To estimate the spontaneous activity of the lambs a pedometer calibrated to measure the number of steps which an animal takes instead of the distance covered was fastened to the leg of the animal and left in place while it wandered in the pasture with no particular stimulus to activity. The time taken was also recorded. The reliability of this method for determining differences in the activity of the normal and thyroidectomized animals did not prove satisfactory. The thyroidless sheep simply followed the flock, and, too, their shorter leg length introduced a pedometer error not easy to correct.

(2) Differences in muscular power were measured by use of an inclined plane, the angle of which could be altered at will. The plane led to the food box and all animals had to pass over it to obtain food. The plane was raised until the thyroidless animals were unable to climb up after the other animals. When food failed as a stimulus the tendency of the sheep to follow a leader served instead.

Doctor Rickey (1925) investigated the influence of thyroid function on the white rat. She studied three phases of the problem, (a) effect of thyroidectomy on maze learning, (b) effect of injecting thyroid gland substance on learning, (c) effect on learning, of feeding thyroid gland substance to normal animals.

She used a control group, a series of normal animals thyroidectomized before and after learning the maze, at different ages ascending from 21 days, and a series of normal animals to which thyroid gland substance was fed in gradual increments, the initial dose beginning at different ages ascending from 21 days. The initial dose in each case was 0.15 grams, the final dose 0.30 grams. Rest periods were given at intervals of five and ten days.

The learning curves of the control group showed a fairly consistent downward slope from the first to the last day of training with two sharp elevations at the points where practice was interrupted. The curves of the series of thyroidectomized animals showed a marked upward slope, after the operation, in the time spent in travelling the maze, and marked fluctuations aside from those due to interrupted practice. Curves of the rats fed on thyroid substance were full of peaks and showed an upward slope with a final flattening, all of which indicates marked variability of performance, slowness and final cessation of learning. She presents her results in terms of average number of minutes or seconds per

trial but gives no statistical constants. Doctor Rickey concludes that in white rats:

(1) "The behavior after thyroidectomy shows a progressive incoördination, the movements becoming slower, less stable, meaningless, and whatever preoperative learning had been acquired is lost. Vitality is reduced, sensitivity decreased, and there is a progressive deterioration of the regulative processes. These effects are more pronounced in the younger animals.

(2) "The effect of injecting thyroid gland substance on learning is practically to eliminate it. There gradually develops a swift and meaningless jumping about and, instead of a dropping off of useless movements, the number of errors actually increases. The instability and hyperactivity increases in the maze and in the home cages, but the effect of the injections seems to decrease with age.

(3) "In general thyroid feeding results in a loss of skill and accuracy which is proportional to the amount fed and inversely proportioned to the age of the animals. The movements become more rapid but less coördinated, and the effects of previous coördination gradually vanish in erratic and convulsive forms of behavior."

5. SUMMARY

An examination of the literature on goiter and on thyroid function in relation to growth, development, and motor control in human and infra-human organisms emphasizes the following facts:

(1) The primary cause of goiter is still unknown.

(2) A lack, loss, or hyposecretion of the thyroid gland, in young organisms, affects both the quantitative and the qualitative development of the organism.

(3) The most constant symptoms of thyroid deficiency in the young growing individual, in both man and

animals, is a disturbance of the process of growth. This takes the form of retardation of growth in length or stature, and in weight, and a decrease in ossification and distortion of anatomical differentiation. This arrestation of development produces a dwarf-like appearance of the organism. Puberty is retarded or absent and mental development does not progress.

(4) While thyroid deficiency retards growth in length, in both sexes in animals, the retardation is greater in the female than in the male, and the inhibition is in direct relation to the age at which the deficiency is initiated.

(5) Hyperactivity of the thyroid gland and thyroid feeding leads to loss of body fat. In animals this loss is considered to balance the organ hypertrophy and so disguise any total weight change.

(6) Hyper-activity of the thyroid increases the basal metabolism whereas hypo-activity decreases it. Feeding doses of thyroid sufficient to bring the basal metabolism in human cretins up to the expected basal metabolism for age and keeping it there causes the actual curve of growth to approximate the expected curve.

(7) Lack or loss of thyroid function and marked increase or decrease of thyroid function, have a profound effect on the central nervous system and the neuromuscular mechanism of higher and lower organisms, and this effect is clearly reflected in the mental and motor life as exhibited in behavior.

(8) Finally, the vast and voluminous literature on the thyroid apparatus reveals little that is definite and conclusive. One is impressed by the large amount of generalization, speculation, and assumption; the very small amount of conclusive experimental proof, and the rich possibilities for further researches in this field.

CHAPTER III

METHOD AND PROCEDURE

A. Development

1. SUBJECTS.—

The subjects consist of 149 goiterous, adolescent girls, ranging in age from twelve to twenty years and a group of 51 non-goiterous girls, ranging in age from twelve to twenty-one years. Of the goiter group only 103 girls participated in the motor control experiments. In both groups by far the greatest number are between fifteen and seventeen years of age. These girls were selected on the basis of a physician's examination and statement that they had some degree of thyroid enlargement, or were entirely free from thyroid enlargement. One physician examined all of the subjects from Baltimore county and another all of the subjects from Allegany county. Could one physician have examined both groups, it would have been highly desirable but such an arrangement was not possible. No measure or estimate of the functional activity of the gland was attempted.

The size of the thyroid was estimated, by the physician, by palpation. With regard to size and type the glands were divided into four groups as follows: (1) slightly but definitely enlarged thyroids; (2) considerably enlarged thyroids; (3) greatly enlarged thyroids; and (4) adenomatas. No other attempt was made to classify the enlargements as to type. However, groups one, two and three were considered collectively as colloid goiters

or diffuse enlargement by the physician, thus giving but two type classes, colloid and adenomata.

Each girl was also examined for tachycardia, tremor and pulse rate. Of the goiterous group twenty showed tachycardia, (having a pulse rate ranging from 100-120 beats per minute), one "rapid heart" and one an "irregular heart;" several showed a fine tremor of the hands and vasomotor instability.

These girls were all students of either the Baltimore County High Schools or the Allegany County High Schools of the State of Maryland, the majority being from the latter county. All volunteered to coöperate in the tests. No girl was taken as a subject unless she and her parents were in full sympathy with the work. Signed form letters of consent were obtained from all parents.

The subjects from Baltimore County are largely of German extraction, a few are Scandinavian, two are Russian and one is Italian. Those from Allegany County are, with one exception, of Scotch, Welch, and English extraction, the majority being Scotch. One subject is Jewish.

The families from which the subjects come are, in general, of the laboring and artisan classes; a few families belong to the professional class. Economically, all are "comfortable" or "well-to-do;" none are "poor," and none are "wealthy."

The hereditary nature of goiter is very definite in the family histories of the majority of the goiterous subjects, the condition having appeared in from three to four generations, and in branches and members of these families living in widely different sections of the country; in other families the hereditary nature of goiter is only suggested or absent, and the condition itself is unrecognized by the majority of the subjects.

An environmental factor of interest in the Allegany County group is that of the water supply of the city of Cumberland. A chemical analysis of this showed that the proportion of iodine contained is the same as that found in regions where there is some endemic goiter. Of the goiterous subjects, 35.9 per cent are residents of Cumberland. Dr. Temanus who made medical examinations of the elementary school children of Allegany County reports for both boys and girls, in the rural districts, an incidence of goiter as high as 80 per cent. Among the girls of the elementary schools of Cumberland he reports an incidence of 30 per cent. Dr. Gardner who examined the high school girls reports an incidence of 75 per cent.

2. PHYSICAL MEASUREMENTS.—Each subject was weighed to the nearest quarter pound, in indoor clothing of light weight, and without shoes. The standing height was taken by means of the "Seaver rod," manufactured by the Narragansett Machine Company of Providence, R. I. Measurements were made without shoes.

To determine whether or not the subject was up to the standard which is set in height and weight for her age, the Wood Tables were used. Any height-weight standard selected would necessarily have been an arbitrary one, at best, and the Wood standards were used because they are based on weights with indoor clothing, but without shoes, which corresponds to the data used here. The Wood standard for age is the nearest birthday, and the same was used in this study, for purposes of comparison, although the age was obtained in more exact terms.

3. MENSTRUAL CYCLE.—So far as possible data on the date of onset of menstruation, with the type of menstruation occurring were obtained; also information as to whether thyroid enlargement preceded, followed, or

occurred simultaneously with the first menstrual period. Unfortunately these data are very incomplete, owing to the fact that neither the subject nor her mother could supply the information, since in many instances the fact that thyroid enlargement existed had been noted by neither.

4. COMPARISON OF PHYSICAL MEASUREMENTS WITH NORMAL STANDARDS

Height.—That one of the most conspicuous consequences of lack of thyroid secretion in early life is a dwarfing of the individual has been amply demonstrated, but that an increase in height, above the average, is the result of thyroid hyperactivity has no experimental proof.

Table 2 shows the percentage number of cases differing from the standard height for age according to the Wood Tables.

Of the forty-four subjects listed as less than two inches overgrown, thirteen or 8.72 per cent agree with the Wood standards for height for age. This is true of four or 7.84 per cent of the thirteen of the non-goiter group who are listed as being less than two inches over height for age.

A comparison of the goiterous subjects with the non-goiterous ones shows that 32.30 per cent of the goiterous girls are from two to four or more inches above the Wood norms in height for age, while 39.20 per cent of the non-goiterous girls are from two to four or more inches below the standard for age. Whether this variation in height is correlated with varying degrees of thyroid activity can in no way be determined, since the method of diagnosis used gives no clue to the functional state of the gland.

TABLE 2.—PERCENTAGE NUMBER OF CASES IN THE GOITER AND NON-GOITER GROUPS DIFFERING FROM THE WOOD STANDARD IN HEIGHT FOR AGE

Differences from normal in inches	Goiter group		Non-goiter group	
	No. of cases	Percent-age	No. of cases	Percent-age
Over +4*.....	13	8.72	3	5.88
+2 to +4.....	35	23.48	5	9.80
Under +2.....	44	29.53	13	25.49
Under -2.....	19	12.75	10	19.60
-2 to -4.....	21	14.09	11	21.56
Over -4.....	17	11.40	9	17.64
Total.....	149	99.97	51	99.97

* Under +2 = between $\frac{1}{4}$ - $1\frac{3}{4}$ inches above the Wood norms in height.
+2 to +4 = 2 to 4 inches above Wood norms.

A correlation has been affirmed, by several writers, to exist between overgrownness and early age of physiological maturation. Among these writers is Baldwin (1914) in his *Iowa Studies*; and later (1925) in the section on "Anthropomorphic Measurements," written by him for Terman's "Genetic Studies of Genius," he reports a computed positive correlation between early maturity and height, for girls of 12 years of $+ .529 \pm .077$. For the ages 11 and 13 years, he reports positive, but less significant correlations, that for 11 years being $+ .360 \pm .090$ and that for 13 years $+ .291 \pm .101$.

In order to determine whether this relationship existed for the groups studied here, coefficients of correlation were computed for the groups combined, for the groups as separate groups, and for the age groups, 12, 13, and

14, these being the only age groups for which there were sufficient numbers to warrant a computation. A positive, but non-significant correlation of $+.11 \pm .06$ was obtained for the goiter group, and a negative one of $-.13 \pm .109$ for the non-goiter group between physiological maturity and height. The coefficients for weight were no less insignificant. Combining the goiter and the non-goiter groups the correlation between height and early maturity is $+.0517 \pm .05$, that between weight and early maturity being $-.122 \pm .05$. The correlations between physiological maturity and height or weight in the age groups 12, 13, and 14 are all without significance excepting that for height in the 12 year group of the goiter group where a coefficient of $+.36 \pm .19$ would indicate a moderate association between these factors. It will be recalled that this is the age group in which Terman found the highest correlation, his figure of $+.529 \pm .077$ showing marked relationship.

The lack of consistency in the sign (see Table 2a) for the separate age groups may be interpreted to be due to one of two factors, either (1) the sparsity of the cases in some age groups or (2) the inaccuracy of the report on the part of the subject as to the date of onset of menstruation. Since the ages of onset, in all age groups tend to bunch at the birthday rather than at from two to six months either side of the birthday, it may be that it is a physiological fact that menstruation does actually occur, on the average in the birthday month. If this be the case the reports are in all probability correct. But until very accurate records are obtained on a large number of girls this must remain an open question. In this study the assumption is advanced that, the subject, not recalling the date accu-

TABLE 2a.—CORRELATIONS BETWEEN PUBESCENCE AND HEIGHT AND WEIGHT IN 135 GOITEROUS AND 48 NON-GOITEROUS ADOLESCENT GIRLS

Age	No.	Control	Physiological maturity	Height with weight
12	10	Height	$+.18 \pm .20$	$+48 \pm .0.8$
		Weight	$-.14 \pm .20$	
13	15	Height	$-.04 \pm .17$	
		Weight	$+.39 \pm .15$	
14	15	Height	$+.19 \pm .17$	
		Weight	$-.33 \pm .16$	
9.10-17.9	48	Height	$-.13 \pm .09$	
		Weight	$-.18 \pm .09$	
Age	No.	Goiter	Physiological maturity	Height with weight
12	36	Height	$+.36 \pm .10$	$+.36 \pm .05$
		Weight	$-.03 \pm .11$	
13	45	Height	$-.03 \pm .10$	
		Weight	$-.05 \pm .10$	
14	36	Height	$+.04 \pm .11$	
		Weight	$-.13 \pm .11$	
9.10-17.9	135	Height	$+.11 \pm .06$	
		Weight	$-.10 \pm .06$	

rately in terms of years, months and days, gave it in terms of the year in which it occurred without reference to deviations on either side of the birthday. This would naturally cause a bunching at the birthday month. As to the relation of height or weight to age of onset of maturity, the indication for the subjects of this study is that overgrownness and early age of maturation are not related. The correlations indicate that, for the separate groups, and for the given ages, the taller and

heavier girls are not relatively more mature, physiologically, than the shorter, lighter girls, except in the 12 year group of the goiter group where the taller girls appear to be physiologically slightly more mature than the shorter girls.

The distribution of age of maturity for the two groups is presented in Table 3 and Chart A. The distribution of height in relation to onset of menstruation is summarized in table 4.

TABLE 3.—DISTRIBUTION OF AGE OF MATURITY IN THE GOITER AND NON-GOITER GROUPS

Age at first menstruation	Goiter	Non-goiter
9-9 yrs., 11 mos.....	1	0
10-10 yrs., 11 mos.....	0	1
11-11 yrs., 11 mos.....	3	4
12-12 yrs., 11 mos.....	36	10
13-13 yrs., 11 mos.....	45	15
14-14 yrs., 11 mos.....	36	15
15-15 yrs., 11 mos.....	11	3
16-16 yrs., 11 mos.....	2	0
17-17 yrs., 11 mos.....	1	0
No information.....	7	1
Not mature.....	7	2
Total.....	149	51

For the goiterous group the average age of advent of menstruation is 13 years and 6 months, with a range of 9 years and 10 months to 17 years and 9 months; that for the non-goiter group is 13 years and 4 months with a range from 10 years and 11 months to 15 years and 10 months. The tallest girl of the goiter group is 67.75 inches (at 16 years) and matured at 15 years and 9 months, only two girls of the group maturing at a later age. The girl of most precocious maturity (9

years, 10 months) is 64 inches tall (at 16 years, 5 months). The shortest girl is 56 inches tall at 14 years, 10 months, and matured at 14 years and 4 months. The only girl diagnosed as exophthalmic is 62 inches tall at 16 years and 2 months and matured at 12 years. The tallest girl in the non-goiter group is 68 inches tall at 17 years and 1 month and matured at 11 years

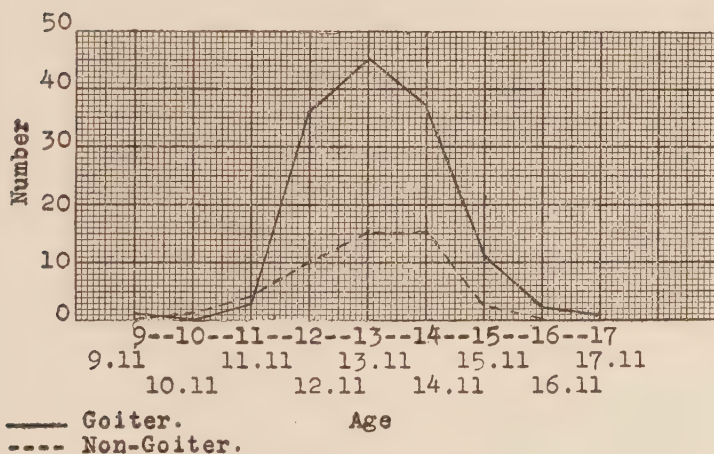


CHART A.—Distribution of age of maturity.

and 3 months. The shortest girl is 58.75 inches tall at 16 years and 9 months and matured at 14 years and 2 months.

Of the goiterous subjects who showed tremor, high pulse rate, etc., all but two are over height and under weight for age. And these two matured at an earlier age than did the others, while the tallest of these thyrotoxic individuals matured at a later age than did the others. These descriptive statements tend to further emphasize the significance of the computed coefficients.

TABLE 4.—HEIGHT IN RELATION TO AGE OF MATURITY.

CONTROL GROUP

First menstruation on or before 13 years*

Height in cms.	Age of first menstruation	No. of cases
152.40	10 yrs., 11 mos.	1
156.21-172.72	11 yrs., 3 mos.-11 yrs., 10 mos.	4
154.94-170.18	12 yrs.-12 yrs., 11½ mos.	10
151.13-168.91	13 yrs.-13 yrs., 4 mos.	8

First menstruation between 14 and 15 years*

153.035-168.275	13 yrs., 6 mos.-13 yrs., 8 mos.	7
149.225-166.37	14 yrs.-14 yrs. 10 mos.	15

First menstruation not before 15 years*

152.7175-166.37	15 yrs.-15 yrs., 10 mos.	3
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GOITER GROUP

First menstruation on or before 13 years*

162.56	9 yrs., 10 mos.	1
156.21-158.115	11 yrs., 9 mos.-11 yrs., 11 mos.	3
151.13-172.72	12 yrs.-12 yrs., 11 mos.	36
147.32-166.37	13 yrs.-13 yrs., 5 mos.	30

First menstruation between 14 and 15 years*

150.495-171.45	13 yrs., 6 mos.-13 yrs., 11 mos., 1 wk.	15
142.24-170.815	14 yrs.-14 yrs., 11 mos.	36

First menstruation not before 15 years*

157.48-172.085	15 yrs.-15 yrs., 9 mos.	11
158.75-160.02	16 yrs., 4 mos.-16 yrs., 10 mos.	2
166.37	17 yrs., 9 mos.	1

* Age at nearest birthday.

The positive, but insignificant relationship found in the goiter group and the negative relationship found in the non-goiter group between age of maturity and height is in direct opposition to the affirmations of Crampton (1908), Baldwin (1914), Weissenberg (quoted by Baldwin), and the computed findings of Baldwin (1925).

These authors all state that there "appears to be a close correlation" between height and pubertal maturation as shown by pubescence. Baldwin, as stated above, in his earlier studies affirms "a direct correlation between advent of first menstruation and different heights of individuals" and in his later studies gives figures which indicate that, for the ages of 11, 12 and 13 years, the taller girls are relatively more mature physiologically than the shorter girls. Among the girls of the latest study, the percentage of subjects of English, German, Jewish, Scotch and Scandinavian extraction is comparatively high, in the order named. The average income of the families from which these girls come is above the income of the average family in the population at large. The nutritional condition of the girls is excellent and, too, they have a high health rating, few having been subject to infection to any extent. All of these factors contribute to, and probably accelerate, an early maturity.

Weissenberg too states that girls of his study who have had their first menstruation before 13 years of age, are, as a rule, taller than those who have not reached this stage in their physiological development before 15 years of age. He finds that girls of the former class measure, on the average, 150-4 cm., whereas he places the normal for that age at 144.5. Girls of the latter class he found below normal for their age.

His results are:

First mens. on or before 13 years	Age at 1st mens.	First mens. not before 15 years
Height, cm.		Height, cm.
152	13.0	142
144	12.0	148
157	11.0	148
154	12.0	150
157	11.0	148
140	13.0	148
147	15.0	158
154.5	12.5	149
145.5	12.5	151
.....		151
.....		148

He also studied the onset of menstruation for 1,273 Jews and 768 Russians and found the average age for the former to be 14 years and 2 months, and for the Russians 14 years and 11 months. Yamasaki found the age to be 15 years for Japanese girls and 17 years for Chinese girls, on the average. It is well known, however, that the women of these races are of relatively short stature. But whether the relatively short stature is directly related to, or dependent upon late onset of menstruation has no satisfactory proof.

It is said that the negro tends to mature earlier than the white. Figures on the relation of maturation to height in negroes and mulattoes would be of interest here for purposes of comparison but are not available.

It will be recalled that the subjects of the goiter group of the study presented here are largely of Scotch extraction. In the non-goiter group a high percentage are of German or Scandinavian origin. The incidence of

childhood infection was high in both groups. The economic status of the families in both groups is much lower than that found in the Terman group. And the functional disturbance of the thyroid gland in the thyroid group indicates a disturbance in the equilibrium of the endocrine system. All of these factors may or may not have contributed to the lack of correlation found between height, weight and age of maturity.

The studies quoted above suggest that there are wide racial differences with respect to time of physiological maturation and with respect to height. That there are wide individual differences within races, for these factors is also probable. But many factors, other than race, are instrumental in producing height; many are also probably instrumental in producing onset of maturity. These factors may be divided into internal and external ones. In the former class heredity, sex and the internal secretions, especially the secretions of the hypophysis and gonads, as well as the thyroid may be included. Experimental and clinical investigations have clearly shown that the hypophysis is capable of exercising a profound influence upon the length of the body and the limbs of the individual, as is evidenced in gigantism. And that the endocrine components of the gonads are also possible factors in regulating height is demonstrated in castrates, where castration leads to persistent body growth. Hoskins says: "That the fervent, early maturing, relatively short races may derive their somatic . . . characteristics, in part, from relative preponderance of the gonadal hormones, is possible, if not probable, just as the more phlegmatic, tall, late maturing races may derive some of their characteristics from relative depression of these hormones."

Hoskin's statement suggests that he would question a general statement to the effect that there is a "direct

correlation between advent of first menstruation and different heights of individuals," in the light in which Crampton, Baldwin and Weissenberg use the statement.

Among the external factors affecting height and onset of maturity may be included those of general nutrition, quantity and quality of diet, general health and childhood infection.

Table 5 shows the percentage number of cases of the goiter sub-groups differing from the Wood standards of height.

TABLE 5.—PERCENTAGE NUMBER OF CASES IN THE GOITER SUB-GROUPS DIFFERING FROM THE WOOD STANDARDS OF HEIGHT

Difference from normal, in ins.	Large		Medium		Small		Adenomata	
	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent
Over +4.....	2	13.33	4	8.88	6	8.57	1	5.26
+2 to +4.....	4	26.66	9	20.00	16	22.85	6	31.57
Under +2.....	5	33.33	12	26.66	24	34.28	3	15.78
Under -2.....	2	13.33	8	17.77	8	11.42	1	5.26
-2 to -4.....	1	6.66	6	13.33	7	10.00	7	36.84
Over -4.....	1	6.66	6	13.33	9	12.85	1	5.26
Total.....	15	99.97	45	99.97	70	99.97	19	99.97
*Normal.....	3	20.00	5	11.11	5	7.14	0	

* Included in groups under +2 and -2.

In the group of large enlargements, 39.99 per cent of the girls are from 2 to 4 or more inches above the average height, 28.88 per cent of the medium, 31.42 per cent of the slight, and 36.83 per cent of the adenomata group. But since size of the thyroid enlargement gives no clue to the degree of activity of the gland it cannot be assumed that the groups having the higher percentage of overgrown individuals are the groups in which there is a hyperactivity of the gland. A statement of findings

is all that can be made. The number of individuals in the large group where the percentage of overgrowth is greatest is relatively small while the number in the slight group is relatively large. The adenomatous group is the group which, on the basis of the classification used, might be assumed to have the subjects with a hyperactive thyroid. It has next to the highest percentage of overgrown individuals.

In line with the study presented is a survey of 100 English goiterous adolescent girls made by Gardner-Hill and co-workers (1925). They found that 79 per cent of their subjects had goiter of the colloid type and that 42 per cent of these colloid subjects had glands that were normal in function, 32 per cent hyperactive and 26 per cent hypo-active.

These workers used Holt's tables for British children for comparison and determined the degree of activity of the gland with the aid of basal metabolism tests. In the colloid series as a whole the majority of the girls were overgrown in height. In the subgroups the highest percentage of overgrowth occurred in the hypothyroid groups. They account for the high percentage here on the assumption that these cases had already passed through a period of hyperactivity and were consequently of the longest duration. The number of individuals in this group was relatively small. It is to be assumed from their percentage table that it is an additive one and that an almost equal percentage of the normal and hyperfunction groups correspond to the Holt standards in height for age, while but 5 per cent of the hypofunction group agree with these standards.

Weight.—Results of a comparison of the weights of the goiterous and non-goiterous subjects of this study with the Wood norms are presented in Table 6 which gives the percentage number of cases differing from the

norms for age. In the goiter group 39.58 per cent of the individuals are under weight, while in the non-goiter group almost the same percentage are overweight, 43.12 per cent being above the Wood norms.

TABLE 6.—PERCENTAGE NUMBER OF CASES DIFFERING FROM THE WOOD STANDARDS FOR WEIGHT

Differences from normal in pounds	Goiter		Non-goiter	
	No. of cases	Per cent	No. of cases	Per cent
+21 and over.....	11	7.38	5	9.80
+16 to +20.....	5	3.35	2	3.92
+11 to +15.....	6	4.02	6	11.76
+6 to +10.....	18	12.08	9	17.64
< +6.....	21	14.09	9	17.64
< -6.....	29	19.46	8	15.68
-6 to -10.....	28	18.79	7	13.72
-11 to -15.....	14	9.39	1	1.96
-16 to -20.....	7	4.69	2	3.92
-21 and over.....	10	6.71	2	3.92
Total.....	149	99.96	51	99.96
Normal.....	4	2.68	1	1.96

Table 7 presents the same data for goiter sub-groups. In the large group 53.32 per cent are from 6 to 21 or more pounds underweight in the, medium group 31.09 per cent, in the slight group 42.84 per cent, and in the adenomatous group 36.82 per cent. The groups having the greatest percentage of underweight individuals are the groups with the large and slight thyroid enlargements.

Gardner-Hill and co-workers, in the study referred to above, give the results of a comparison of weight in their series of colloid goiter cases with the Holt standards,

but here use a cumulative not an additive percentage table. In the normal function group 49.00 per cent of the cases are within $\frac{1}{2}$ stone (7 lbs.) of the normal standard. This percentage includes the deviations on both the plus and minus side of the norm. In the hyper-function group 40 per cent are below the average weight to the extent of 1 stone (14 lbs) or more, while 56 per cent are below the average to the extent of $\frac{1}{2}$ stone or more. The reverse condition occurs in the hypofunction group. There 45 per cent of the cases are above the average weight to the extent of one stone or more, while 60 per cent are above the average weight to the extent of $\frac{1}{2}$ stone or more.

TABLE 7.—PERCENTAGE NUMBER OF CASES OF THE GOITER SUB-GROUPS DIFFERING FROM THE WOOD STANDARDS FOR WEIGHT

Differences from normal, in lbs.	Large		Medium		Small		Adenomata	
	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent
+21 and over.	0	0.00	4	8.88	6	8.57	1	5.26
+16 to +20..	1	6.66	1	2.22	3	4.28	0	0.00
+11 to +15..	1	6.66	2	4.44	1	1.42	2	10.52
+6 to +10...	1	6.66	5	11.11	6	8.57	6	31.57
<+6.....	2	13.33	10	22.22	9	12.85	0	0.00
<-6.....	2	13.33	9	20.00	15	21.42	3	15.78
-6 to -10...	5	33.33	6	13.33	14	20.00	3	15.78
-11 to -15..	1	6.66	3	6.66	8	11.42	2	10.52
-16 to -20..	0	0.00	3	6.66	3	4.28	1	5.26
-21 and over.	2	13.33	2	4.44	5	7.14	1	5.26
Total.....	15	99.96	45	99.96	70	99.95	19	99.95
Normal.....	1	6.66	3	6.66	0		0	

They conclude that, where goiter is of the "purely physiological" type, little variation from the normal is found, but in other cases where abnormal thyroid

activity is present, a tendency is seen, in hyperthyroidism, for the individual to be underweight and in hypothyroidism to be overweight.

Menstruation.—While a direct relationship has never been demonstrated to exist between the thyroid gland and the ovaries, a relationship is very generally assumed, even though the assumed association is not clearly understood. Abnormalities of menstruation have frequently been described in thyroid dysfunction and the consensus of opinion is that both myxedema and exophthalmic goiter may be accompanied by either amenorrhea or menorrhagia, and that small goiters associated with mild degrees of thyrotoxicosis are often accompanied by dysmenorrhea without associated anatomic changes in the pelvic organs.

The only observations found in the literature on the menstrual rhythm in adolescent goiter are those of Gardner-Hill and his co-workers (1925). Their results are:

	Colloid normal	Colloid hyper- function	Colloid hypo- func- tion*	Exoph- thalmic
Mens. not started.....	49 %	14 %	0 %	0 %
Mens. normal.....	42	45	48	28
Menorrhagia.....	3	0	48	0
Delayed, irregular of scant.	3	27	6	0
Periods of amenorrhea.....	3	14	0	72

* There is probably a typographical error in the report for this group, as the figures add to 102 % instead of 100 %.

It appears, from this table, that the character of menstruation tends to vary inversely with the degree of thyroid activity, i.e., where hyperthyroidism is present,

the periods tend to be delayed, irregular and scanty or absent, while in cases of hypothyroidism there is more frequently a tendency to menorrhagia. In the colloid group menstruation is undisturbed in about one-half of the cases, while in the exophthalmic group there is some degree of amenorrhea in three-fourths of the cases.

In regard to the classification of character of menstruation, used by these writers, it is to be noted that the fourth and fifth types would, according to the usual classification used, be combined as one. Delayed, irregular and scanty menstruation are usually considered to constitute amenorrhea. On the other hand dysmenorrhea or painful menstruation, which has been found by some writers to be associated with hyperthyroidism, by others with hypothyroidism, is not included in their classification. Had the usual classification been observed and had there been no cases of dysmenorrhea, there are very nearly the same number of cases in the hyperfunction group in which there is delayed, scanty, or irregular menstruation, as there are cases with normal menstrual function. Their exophthalmic group is, relatively, very small.

The high percentage of individuals in the normal function group, who have not matured is considered, by these authors, to be expected, since in many of these individuals the goiter is of more recent origin.

In considering the relation of the onset of menstruation to onset of thyroid enlargement, these writers find, that in 76 per cent of the cases of normal function, colloid goiter the onset of enlargement, precedes the onset of menstruation while in the exophthalmic type, in 90 per cent of the cases, menstruation precedes the goiter.

Table 8 gives the percentage number of cases in the goiter and the non-goiter group of this study with the type of menstruation occurring. In both groups

menstruation is undisturbed in about one-half of the number of cases. Whether the 16.10 per cent of dysmenorrhea and the 22.81 per cent of amenorrhea in the goiter group are associated with hyper- or hypothyroidism cannot be determined on the basis of the diagnoses used. That hyperthyroidism is associated with amenorrhea has as many supporters as that hypothyroidism is. The same is true of dysmenorrhea. It is noteworthy that menorrhagia does not occur in either group.

TABLE 8.—TYPE OF MENSTRUATION OCCURRING

Type of menstruation	Goiter group		Non-goiter group	
	No. of cases	Percent-age	No. of cases	Percent-age
Not mature.....	8	5.36	2	3.92
Menorrhagia (profuse)..	0	0.00	0	0.00
Amenorrhea (delayed, irregular or scanty)...	34	22.81	8	15.68
Dysmenorrhea (painful).	24	16.10	14	27.45
Normal.....	72	48.32	26	50.98
No information.....	11	7.38	1	1.96
	149	99.97	51	99.99

Table 9 gives the percentage number of cases in the four goiter sub-groups with the type of menstruation occurring.

From this table it will be seen that the percentages for each menstrual type in each group are comparable to those for the goiter group as a whole. Menstruation is normal in from one-half to three-fourths of the cases in all four groups. Amenorrhea is more frequent than dysmenorrhea in all groups but the adenomatous group and there the reverse is true.

TABLE 9.—TYPE OF MENSTRUATION OCCURRING IN GOITER SUB-GROUPS

Type of menstruation	Large		Medium		Slight		Adenomatous	
	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent
Not mature.....	0	0	3	6.66	5	7.14	0	0
Menorrhagia (profuse).....	0	0	0	0	0	0	0	0
Amenorrhea (delayed, irregular or scanty).....	4	26.66	8	17.77	18	25.71	4	21.05
Dysmenorrhea (painful).....	3	20.00	7	15.55	13	18.57	1	5.26
Normal.....	5	33.33	27	60.00	33	47.14	7	36.84
No information.....	3	20.00	0	0	1	1.42	7	36.84
	15	99.99	45	99.98	70	99.98	19	99.99

Table 10 gives the relation of onset of thyroid enlargement to onset of menstruation. This information unfortunately is lacking for slightly over one-half of the individuals. These facts could not be recalled accurately by either the girl or her mother. In many instances the fact that thyroid enlargement existed had never been observed by either.

TABLE 10.—RELATION OF ONSET OF GOITER TO ONSET OF MENSTRUATION

Classification	Number of cases	Percentage
Goiter before menstruation.....	34	22.81
Goiter after menstruation.....	19	12.75
Goiter not noticed.....	39	26.17
Goiter and menstruation simultaneous.....	6	4.02
No information.....	43	28.85
Not mature.....	8	5.36
	149	99.96

For individuals for whom information was obtained thyroid enlargement preceded menstruation in 22.81 per cent of the cases, and in 12.75 per cent of the cases the reverse was true. In 4.02 per cent of the cases the enlargement and the advent of maturity were simultaneous.

Table 11 gives the same information for the goiter sub-groups. In all groups, excepting the adenomatous group, enlargement of the thyroid preceded menstruation in a high percentage of the individuals.

TABLE 11.—RELATION OF ONSET OF GOITER TO ONSET OF MENSTRUATION
Goiter Sub-groups

Classification	Large		Medium		Slight		Adenomatous	
	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent	No. of cases	Per cent
Goiter before menstruation....	6	40.00	14	31.11	13	18.57	1	5.26
Goiter after menstruation.....	3	20.00	7	15.55	8	11.42	1	5.26
Goiter not noticed.....	3	20.00	9	20.00	26	37.14	1	5.26
Goiter and menstruation simultaneous.....	0	0.00	6	13.33	0	0.00	0	0.00
No information.....	3	20.00	6	13.33	18	25.71	16	84.21
Not mature.....	0	0.00	3	6.66	5	7.14	0	0.00
	15	100.00	45	99.98	70	99.98	19	99.99

The data presented here on the menstrual rhythm in goiterous adolescents are because of their meagerness, indecisive, but are of interest in that they suggest questions which might be answered by further investigation on large groups of individuals.

5. SUMMARY AND CONCLUSIONS.—This section of the paper contains the measurements of height and weight, and a comparison of these with the Wood norms; also a statement of the menstrual rhythm in 149 goiterous, adolescent girls and 51 non-goiterous adolescent girls.

Conclusions as to the influence of thyroid activity on height, and weight, and as to the menstrual function in goiterous adolescents would be unwarranted from the data presented. All that can be said is:

1. That the goiterous girls of this study tend to be slightly taller than the non-goiterous girls of the same age, using the Wood tables as standards of comparison. In the former group 32.20 per cent of the subjects exceed the Wood standards by from 2 to 4 or more inches. In the latter group 39.20 per cent of the subjects fall from 2 to 4 or more inches below these standards.

2. The goiterous girls tend also to be slightly more slender than the Wood standards, while the non-goiterous girls tend to be overweight. The percentage of underweight in the goiter group is 39.58. The percentage of overweight in the non-goiter group is 43.12.

3. Height and onset of menstruation are negatively or insignificantly correlated. The coefficient of correlation for the goiter group is $+.11 \pm .06$; that for the non-goiter group is $-.13$ with a probable error of $\pm .09$.

4. Menstruation is normal in 48.32 per cent of the goiterous subjects and in 50.98 per cent of the non-goiterous subjects.

5. Thyroid enlargement preceded menstruation in 22.81 per cent of the subjects, the reverse being true for 12.75 per cent. In 4.02 per cent of the cases thyroid enlargement and menstruation occurred simultaneously.

B. Motor Control Experiments

Previous motor control experiments on goiterous individuals have been made on thyrotoxic subjects exclusively and have been concerned primarily with a measure of tremor. The present experiment is

concerned particularly with a study of inhibition of movement or steadiness; also with speed, coördination and fatigue.

1. APPARATUS AND METHODS.—The following series of tests were given in the order stated: Steadiness, Motor coördination, Dynamometer, and Tapping.

Since all of these tests require, not finger or hand movements, but rather movements essentially controlled by the arm or wrist, they are particularly well suited for detecting irregularities of motor control in goiterous individuals. It will be recalled that P. Marie showed that the irregularities of hand movement in these persons are not due to unsteadiness of the hand *per se*, but are communicated to the hand from the segments of the arm.

Each subject was given the series of tests, at as nearly as possible the same time of day each day for one school week, at the school which she attended. Occasionally a holiday intervened or slight illness prevented the girl from coming the entire week and hence there are a few individuals who took the tests two, three, or four days instead of five successive days; or when Saturday and Sunday intervened the five days were not successive.

As the tests involved a loss to each subject, of one-half hour each day for one week of class work, they necessarily had to be limited in kind and number. Kymographic records of pulse rate, and blood pressure readings would have added value to the work, as also would have basal metabolism and blood sugar tests. These however, were, under the conditions under which the subjects could be tested, out of the question. The factor of time also precluded the use of graphic registration in the tests given.

The tests were given between 9:00 a.m. and 3:00 p.m. The work was done in the various schools in a teachers' rest room, a library or small room adjoining the assembly

hall, with no one present except the subject and the experimenter.

Steadiness Test.—The Dunlap improved form of steadiness plate was used connected with a telephone receiver. The plate, receiver, and stylus were wired in series with two dry cells. The subject stood before the brass plate, with the shoulder of the arm used directly opposite and on a level with the top of the plate* which was tilted at an angle of fifteen degrees. Holes two, four, six, eight, and ten were used in the series from large to small. The right and left hands were tested, alternately, for each series of holes.

The subjects were instructed to hold the stylus pencil fashion and to insert it into the hole one inch, resting it on the lower edge of the circle; then to step back a few inches extending the arm so that the fore-arm made an angle slightly over ninety degrees with the upper arm, and to free the arm from all contact with the body. At the words, "ready, now," the subject was instructed to free the needle from contact with the plate and to hold it, so that, if possible, no contacts were made until told to "stop."

After the word "stop" the subject rested one minute and then repeated the procedure with the left hand. The stop watch was started at the word "now" and eighteen seconds were allowed for each hand. Contacts were not counted during the first three seconds.

In evaluating the data the hole in which the contacts did not exceed twelve was used as a score. The value of this score was computed in accordance with the method used by Dewy, Child and Ruml with the following

*Accuracy in adjusting the plate on successive days for the same individual would have been augmented had a centimeter scale been cut on the vertical rod to which the brass plate is attached.

modifications. Hole 10 which is not included in their table of values was assigned a zero value, i.e., it was not weighted and so nothing was added to the number of contacts in the final score. Where the contacts for the largest hole used exceeded twelve, as it did with three subjects, a score of one hundred and eighteen was assigned, i.e., thirteen was added to the last value of the Dewy, Child and Ruml table of values.

Motor Coördination.—The blanks used for this test were two forms of the Hopkins series, (1) the Dunlap form and (2) the Johnson-Dunlap form. For these tests the blank with the larger pattern was presented first. The subject was seated at the table with the tracing-blank squarely in front of her. She held the pen or pencil as suited her and was instructed to place the tip on the x at the left hand side of the page, then to free the hand and arm from all contact with the table or body, holding the blank in position on the table with the left hand. With the metronome set at sixty beats per minute she was instructed, at the word “go,” to begin tracing a path between the lines without touching the sides and, in tracing each section, to make one stroke of the pen or pencil to one beat of the metronome. In transferring from one line to the next no extra beats of the metronome were allowed. The score consisted in the number of contacts made.

The stop watch was started at the word “go” and the time taken to complete each blank recorded along with the contacts made. Each subject was attentively watched to see that the beats of the metronome were followed.

Before presenting the first blank each subject was given five practice periods in rhythm on small squares drawn on paper. Four seconds were required for each period.

If rhythm was not secured in the five periods, more practice was given. The stop watch was started at the beginning of the first stroke and the time required to complete each square recorded. These records were not subjected to statistical analyses.

Dynamometer.—A Smedley's dynamometer and a metronome were used for this test. The right and left hands were used alternately, beginning with the right hand one day and with the left hand the following day.

The subject was seated at the table with the arm outstretched, palm down but dial of the instrument up. The dynamometer was adjusted to the hand of each subject and the same adjustment noted and used each day. The metronome was set at sixty beats per minute.

The subject was told that the experimenter would say: "Ready, one, two, pull," to four successive beats of the metronome and that the subject was to pull at the word "pull," exerting a maximal grip, quickly, and to let go immediately, not sustaining the pull. The reading on the dial was recorded after each pull, and at the next five beats of the metronome the hand of the dynamometer was set back to zero, by the experimenter, the instrument transferred by the subject to the left hand and at the following beat the above procedure was repeated. The hands were alternated until a series of twenty pulls had been made with both hands. The score given was the average of twenty grips. As a measure of fatigue an average of the first two grips was compared with an average of the last two grips and the average of the twenty grips.

Tapping Test.—The Johns Hopkins double tapping plate with light weight wooden base, and not clamped to the table, was used for this test. The plate was wired in current with a metal stylus and counter. The subject

was instructed to stand a few inches away from the table on which the tapping plate stood, to hold the stylus pencil fashion, or any way most comfortable, provided the same method was used throughout the successive trials. Using the right hand first, she was instructed at the word "go" to begin tapping, striking first one plate and then the other, as rapidly as possible and to continue tapping until told to "stop;" also to pay attention to nothing but her tapping until she heard the word "stop," then to rest one-half minute and repeat the procedure with the left hand. These instructions were followed until five records of sixty seconds each had been made each day for both hands. The score for each sixty seconds was recorded and the records of the five sixty-second trials averaged for both hands, i.e., the right and the left hand both received an average of five sixty-second trials as a score for the day. The time was measured by the stop watch which was started at the word "go" at the beginning of the experiment, and stopped at the word "stop" at the end of the experiment, i.e., at the close of fifteen minutes from the first "go."

In making the mathematical computations for all of the tests decimals were used as such, but in the tabulations, excepting those of the statistical constants, each number was corrected to the nearest unit so that only whole numbers appear in the body of the tables.

Two measures of absolute variability were used—the entire range and the standard deviation. The latter measures the closeness with which the figures for the individual cases are grouped about the average, and affords a criterion for testing an individual case in comparison with the average. Other things being equal, a large standard deviation means that the individuals in the group differ more from one another than if the standard deviations were small.

TABLE I.—STEADINESS TEST. DEWY, CHILD AND RUMML METHOD OF SCORING

Goiter			Non-goiter		
Subject	Right hand	Left hand	Subject	Right hand	Left hand
And.....	69	86	Alb.....	89	89
App.....	50	39	Bay.....	55	91
Ask.....	103	118	Bil.....	100	92
Atk.....	73	80	Bro-1.....	35	48
Aye.....	67	61	Bro-2.....	41	46
Bar.....	51	56	Bul.....	47	64
Ber.....	42	56	Car.....	58	77
Bla-1.....	64	68	Che.....	92	94
Bla-2.....	53	68	Cla.....	39	65
Boc.....	47	86	Cle.....	47	55
Boo.....	55	63	Cog.....	40	55
Bow.....	65	67	Col.....	54	88
Bro.....	51	62	Cor.....	51	57
Cha-1.....	81	86	Din.....	100	102
Cha-2.....	74	101	Fie.....	34	43
Clo.....	79	82	Fis.....	86	97
Coc.....	75	118	Gre.....	43	73
Con.....	68	74	Gri.....	90	118
Coo.....	49	68	Gro.....	48	49
Cro-1.....	63	87	Hal.....	48	67
Cro-2.....	40	53	Ham.....	43	56
Cro-3.....	86	95	Har.....	74	74
Cun.....	90	77	Hil.....	59	60
Dan-1.....	65	80	Hof.....	80	99
Dan-2.....	46	67	Ire-1.....	58	75
Dav-1.....	61	74	Ire-2.....	73	85
Dav-2.....	81	94	Kno.....	58	56
Dic.....	41	54	Kru.....	98	102
Die.....	58	63	Lee.....	56	78
Dun.....	63	47	Llo.....	66	65
Edw.....	47	63	May.....	91	98
Eic.....	70	90	Mui.....	69	84
Eve.....	47	56	Neu.....	74	89
Far.....	61	61	Oyl.....	52	67
Fie.....	67	76	Pow.....	40	48
Fin.....	46	57	Rad.....	51	58
Fle.....	58	79	Ras.....	61	71
Flo.....	57	84	Rob.....	73	83
Fre.....	95	118	Sew.....	62	80
Gat.....	60	74	Sne.....	52	58
Gri-1.....	79	82	Tho-1.....	30	53
Gri-2.....	77	80	Tho-2.....	73	101
Ham.....	53	65	Tow.....	53	64
Har.....	54	78	Was-1.....	50	73

TABLE I.—(Continued)

Goiter			Non-goiter		
Subject	Right hand	Left hand	Subject	Right hand	Left hand
Hig.....	46	60	Was-2.....	68	74
Him.....	68	98	Wea.....	90	102
Hin.....	65	60	Web.....	51	75
Hip.....	49	80	Whi.....	75	88
Hug.....	46	73	Wie.....	82	43
Hyd.....	67	69	Wil.....	72	81
Jen-1.....	80	89	Wis.....	42	61
Jen-2.....	67	95			
Kel.....	53	65			
Klo.....	47	47			
Lag.....	70	95			
Lan.....	35	43			
Lay.....	83	93			
Lee.....	57	72			
Lew.....	69	93			
Lip.....	57	59			
Llo.....	65	101			
Luc.....	46	56			
Mar.....	59	55			
Mas.....	81	95			
Mcg.....	50	70			
Mig-1.....	83	94			
Mig-2.....	72	79			
Mil-1.....	62	80			
Mil-2.....	74	71			
Mil-3.....	46	46			
Mos.....	92	101			
Nol.....	81	92			
Ode.....	63	66			
Odg.....	99	103			
Olm.....	68	79			
Pha.....	30	45			
Ple.....	60	67			
Plu.....	52	71			
Poo.....	94	89			
Pre.....	61	76			
Pri.....	62	79			
Rei.....	63	51			
Ric.....	47	85			
Rob.....	54	73			
Rod.....	94	92			
Rut.....	42	58			
Sal-1.....	26	41			
Sal-2.....	42	76			
Sca.....	69	89			

TABLE I.—(Continued)

Goiter			Non-goiter		
Subject	Right hand	Left hand	Subject	Right hand	Left hand
Sch-1.....	87	97			
Sch-2.....	48	66			
Sho.....	86	100			
Sip.....	96	102			
Sto.....	79	93			
Str.....	51	58			
Ten.....	80	79			
Twi.....	56	47			
Wag.....	49	80			
Wal.....	81	86			
War.....	45	53			
Wat.....	66	53			
Web.....	77	99			
Wri.....	48	66			

Goiter right		Non-goiter right	
Number tested.....	103	Number tested.....	51
Total score.....	6526	Total score.....	3173
Mean.....	63.3 ± 1.0738	Mean.....	62.2 ± 1.7734
M.D.....	13.1	M.D.....	16.01
S.D.....	$16.143 \pm .7587$	S.D.....	18.773 ± 1.2549
Range.....	26 to 103	Range.....	30 to 100

Difference in means.....	1.1 ± 2.0731
D.....	
P.E.D.....	.5306
Difference in S.D.....	2.63 ± 1.4664
D.....	
P.E.D.....	1.7935

Goiter left		Non-goiter left	
Number tested.....	103	Number tested.....	51
Total score.....	7743	Total score.....	3771
Mean.....	75.1 ± 1.1818	Mean.....	73.9 ± 1.7300
M.D.....	14.79	M.D.....	15.4
S.D.....	$17.767 \pm .8351$	S.D.....	18.314 ± 1.2242
Range.....	39 to 118	Range.....	43 to 118

Difference in means.....	1.2 ± 2.0951
D.....	
P.E.D.....	.5727
Difference in S.D.....	$.547 \pm 1.4819$
D.....	
P.E.D.....	.3691

The ratio of the difference between the means and the standard deviations of the groups to the probable error of the differences are given for each test. These ratios serve as indices of reliability from which an expression of the degree of the probability of a real difference between the two groups can be expressed. (Tables I-VIIId.)

The frequency distributions are given to indicate the general trend of results. (Figures 2-36.) They emphasize the relative constancy of performance of the groups as a whole and show the total range of reactions and the overlapping.

2. ANALYSIS OF MATERIAL

COMPARISON OF THE GOITER AND NON-GOITER GROUPS IN THE STEADINESS TEST

As Wells contends, the steadiness test has little to do with motor accuracy, but is rather a crude measure of muscular tremor. It is also a measure of attention and of the ability to inhibit movement. In the plate used in the present study, holes 10 and 11, the former with a diameter of only $\frac{9}{64}$ of an inch, and the latter with an even smaller diameter give a measure of the rate of fine tremor, at least in the horizontal plane, fairly accurately, but not a measure of the amplitude of the tremor. In criticism it must be agreed, though, that respiratory movements and variations in attention affect and confuse results, and these errors are difficult to control, and impossible to measure.

The results of this test are summed up in Table I and the following curves. A comparison of the central tendencies of the true distributions shows no material difference in achievement. The goiter group with a mean score of 63.3 contacts for the right hand and one of 75.1 contacts for the left hand, stands only 1.1 and 1.2 points for the right and left hands respectively, above the non-goiter group. Both groups are on practically the same level of performance. And the two

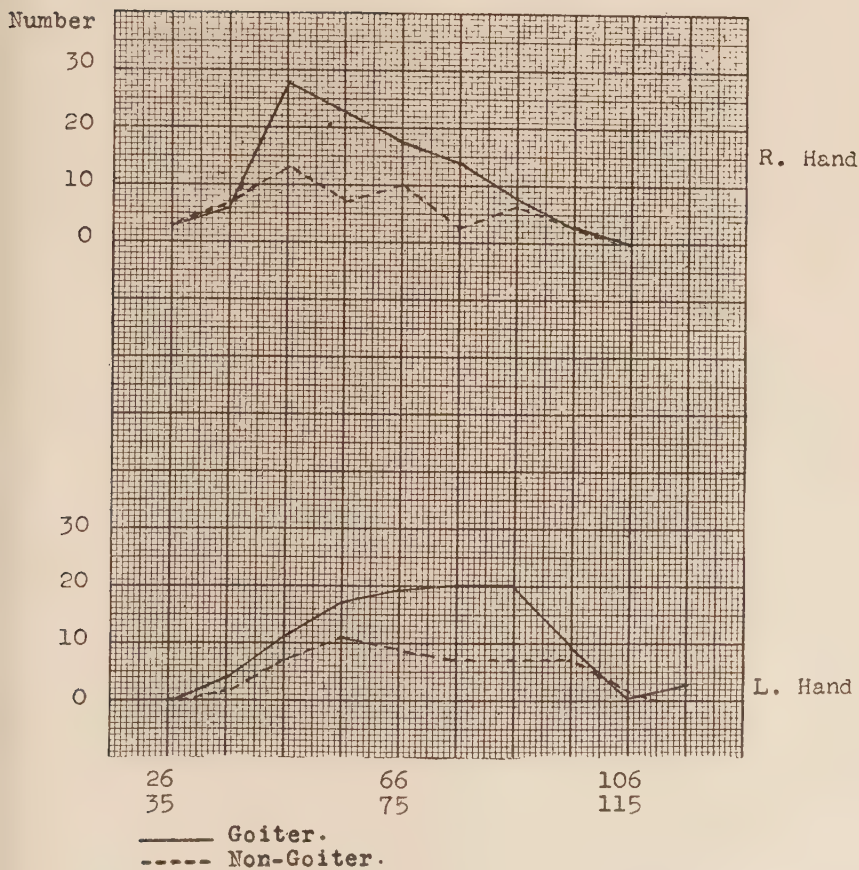


FIG. 2.—Steadiness test. Distribution of gross scores.

groups show approximately the same variability as indicated by the standard deviation. This constant for both hands in the two groups is about the same, being 16 and 18 for the right and left hands respectively for the goiter group and 17 and 18 for the right and left hands of the non-goiter group. Differences in the means as compared with their standard deviations are small showing that the group variations are mere chance ones. That there is not a difference, of statistical significance, is also borne out by the reliability quotients. The significance of the data is even more readily apparent when presented in graphic form, in Figure 2.

The scores which deviated farthest below the mean (the poorest) were made in the goiter group and by subjects who showed tremor in one or both hands. For example, Coc. who made a score of 118 contacts with the left hand and 75 with the right, had a pulse rate of 120 beats per minute, marked tremor of the left hand, slight exophthalmia, and was markedly unstable emotionally. She was coöperative and interested in making a good score, as was evidenced by the fact that she practiced holding a pin in a hole each evening as a means to improving her score, but a restless inability to attend, for even 18 seconds to the task in hand, as well as the tremor, made her chances of a high score negligible. Ask. of the goiter group who made a score of 103 contacts for the right hand and 118 for the left had a pulse rate of 120 and while she had no obvious tremor of the hand, she showed marked choreic movements of trunk, shoulders, and arms which made it impossible to hold the needle, in even the largest hole, without contacts. Fre. of the goiter group, who made a score of 95 contacts with the right hand and one of 118 with the left, had a pulse rate of 100 and slight tremor of the hands. Llo. whose scores for the right and left hands respectively

were 65 and 101, had a pulse rate of 118 beats per minute, but no tremor of the hands. The other three, Mas., Odg., and Sip., who made markedly low scores, had pulse rates of 76, 96 and 92 respectively, but no tremor. All of the subjects mentioned were taking iodine or some kind of thyroid preparation for dysfunction of the thyroid gland. However, of these, Mas. showed no symptoms of thyrotoxis and her low score is probably due to other causes, such as poor attention, respiratory movements, etc. Of the three in the non-goiter group who made particularly poor scores, Bil. had "some nervous trouble" which had affected the right arm, was subject to fainting spells, and was "always ill." Wea. had had infantile paralysis.

It must be conceded then, even though these groups, as groups, show no significant variations, by the method of statistical analyses applied, yet an analysis of individual scores shows that, of the outstanding low scores, every such score, in the goiter group, with one exception, belongs to a subject who exhibits some of the characteristics of thyrotoxis, and strongly suggests that the inferiority of performance is directly related to this condition. That, in the non-goiter group, the low scores, with one exception, belong to subjects who have or have had some nervous disorder is also significant. The exceptional scores at either extreme, are too few to affect the groups as a whole, and their significance becomes apparent only on individual analysis.

It is unfortunate that there are no figures available for comparison. The only similar study reported is that of Dorcus (1925) on Athletes in coördination tests. But because of the wide difference in methods used in his study and the present study the final results are not comparable.

TABLE Ia.—COMPARISON OF GOITER SUB-GROUPS. STEADINESS TEST. DEWY, CHILD AND RUMI METHOD OF SCORING

Large thyroid enlargement			Medium thyroid enlargement			Small thyroid enlargement			Adenomata		
Score			Score			Score			Score		
Subject	Right hand	Left hand	Subject	Right hand	Left hand	Subject	Right hand	Left hand	Subject	Right hand	Left hand
Boc.....	47	86	Ask.....	103	118	And.....	69	86	Atk.....	73	80
Cro-3.....	86	95	Bow.....	65	67	App.....	50	39	Bar.....	51	56
Dan-2.....	46	67	Cha-1.....	81	86	Aye.....	67	61	Coc.....	75	118
Dic.....	41	54	Con.....	68	74	Ber.....	42	56	Dic.....	58	63
Flo.....	57	84	Dan-1.....	65	80	Bla-1.....	53	68	Dun.....	63	47
Gat.....	60	74	Dav-1.....	61	74	Bla-2.....	53	68	Hin.....	65	60
Hig.....	46	60	Eve.....	47	56	Boo.....	55	63	Hip.....	49	80
Kel.....	53	65	Far.....	61	61	Bro.....	51	62	Lag.....	70	95
Lip.....	57	59	Fin.....	46	57	Cha-2.....	74	101	Lee.....	57	72
Lil.....	65	101	Fie.....	58	79	Clo.....	79	82	Mas.....	81	95
Mil-3.....	46	46	Gri-1.....	79	82	Coo.....	49	68	Mig-1.....	83	94
Pla.....	30	45	Him.....	68	98	Cro-1.....	63	87	Mig-2.....	72	79
Poo.....	94	89	Jen-2.....	67	95	Cro-2.....	40	53	Nol.....	81	92
Sho.....	86	100	Lan.....	35	43	Cun.....	90	77	Olm.....	68	79
Sto.....	79	93	Lay.....	83	93	Dav-2.....	81	94	Pie.....	60	67
			Luc.....	46	56	Edw.....	47	63	Pri.....	62	79
			Meg.....	50	70	Eic.....	70	90	Rel.....	63	51
			Mil-2.....	74	71	Fie.....	67	76	Str.....	51	58
			Mos.....	92	101	Fre.....	95	118	Web.....	77	99
			Ode.....	63	66	Gri-2.....	77	80			
			Rob.....	99	103	Han.....	53	65			
			Rod.....	54	73	Har.....	54	78			
				94	92	Hug.....	46	73			

Large-right	Number tested	15	Medium-right	Number tested	29	Small-right	Number tested	40	Adenomata-right	Number tested	19
	Total score	893		Total score	1914		Total score	2460		Total score	1259
	Mean	59.5 ± 3.1743		Mean	66 ± 2.2732		Mean	61.5 ± 1.6545		Mean	66.2 ± 1.6744
	M.D.	15.03		M.D.	14.96		M.D.	12.8		M.D.	9.32
	S.D.	18.213 ± 2.2458		S.D.	18.1317 ± 1.6070		S.D.	15.5032 ± 1.1696		S.D.	10.799 ± 1.1824
Large-left	Range	30-94		Range	35-103		Range	26-96		Range	49-83
	Number tested	15	Medium-left	Number tested	29	Small-left	Number tested	40	Adenomata-left	Number tested	19
	Total score	1118		Total score	2218		Total score	2943		Total score	1464
	Mean	74.5 ± 3.2599		Mean	76.4 ± 2.2222		Mean	73.5 ± 1.8146		Mean	77.05 ± 2.8355
	M.D.	16.8		M.D.	14.38		M.D.	13.8		M.D.	14.99
	S.D.	18.7042 ± 2.3063		S.D.	17.7253 ± 1.5710		S.D.	17.0029 ± 1.2828		S.D.	18.2741 ± 2.0009
	Range	45-101		Range	43-118		Range	39-118		Range	47-118

When the goiter group is subdivided according to original diagnoses, and a statistical analysis made of these four groups, no significant variations in the ability to inhibit movement are found between these groups, as groups. For the right hand the means for the large, medium, and small enlargement, and adenomata groups are 59.5, 66, 61.5, and 66.2 respectively, while those for the left hand are 74.5, 76.4, 73.5, and 77. The large, medium, and slight groups for the right hand, and all groups for the left hand show about the same variability as measured by the standard deviation. A uniformity of scores for the right hand in the adenomata group accounts for the comparative difference in variability in this group.

It will be recalled that the points of central tendency for the right and left hands of the goiter group as a whole were 63.5 (S.D. 16.1) and 75.1 (S.D. 17.6) respec-

TABLE Ib.—DIFFERENCES IN CONSTANTS FOR GOITER SUB-GROUPS
IN STEADINESS TEST

Groups compared	Right hand			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	6.5 $\pm$ 3.9043	1.6	0.0813 $\pm$ 2.7615	0.029
Large-slight.....	2.0 $\pm$ 3.5796	0.55	2.7098 $\pm$ 2.5321	1.07
Large-adenoma.....	6.7 $\pm$ 3.5888	1.8	7.414 $\pm$ 2.5380	2.9
Medium-slight.....	4.5 $\pm$ 2.8115	1.6	2.6285 $\pm$ 1.9875	1.3
Medium-adenoma.....	0.2 $\pm$ 2.8233	0.07	7.3327 $\pm$ 1.9951	3.6
Slight-adenoma.....	4.7 $\pm$ 2.3539	1.9	4.7042 $\pm$ 1.3289	3.5
	Left hand			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	1.9 $\pm$ 3.9452	0.481	0.9789 $\pm$ 2.7905	0.350
Large-slight.....	1.0 $\pm$ 3.7309	0.268	1.7013 $\pm$ 2.6390	0.644
Large-adenoma.....	2.55 $\pm$ 4.3192	0.590	.4301 $\pm$ 3.0532	0.140
Medium-slight.....	2.9 $\pm$ 2.6888	1.078	.7224 $\pm$ 2.0282	0.356
Medium-adenoma.....	.65 $\pm$ 3.6009	0.180	.5488 $\pm$ 2.5439	0.215
Slight-adenoma.....	3.55 $\pm$ 3.3647	1.055	1.2712 $\pm$ 2.3767	0.534

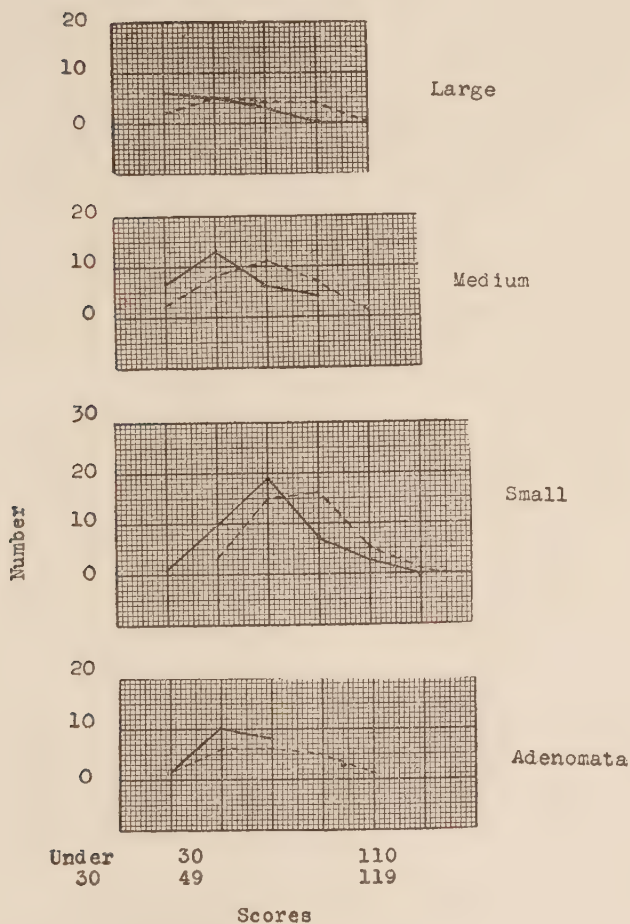


FIG. 3.—Steadiness test. Distribution of scores.

tively. These figures neither exceed nor fall behind the corresponding figures for the sub-groups to an appreciable degree. Nor is there a significant difference between the constants for the goiter sub-groups and those of the control group. Also the reliability quotients are, without exception, less than four in both the larger groups and the sub-groups. This all emphasizes the homogeneity of the material and the constancy of level of performance of these subjects.

A detailed analysis of these sub-groups is presented in Tables Ia and Ib and Figure 3.

COMPARISON OF THE GOITER AND NON-GOITER GROUPS IN THE COÖRDINATION TEST

1. *Johnson-Dunlap Form.*—These tests as Hollingworth has stated “include along with the factors of steadiness and speed, which are essentially motor or physiological, the more strictly mental factor of coördination. Success in these tests requires not only, that a single set of muscles be brought into harmonious action, as in the tapping test, but also that several sets be coördinated with each other, under the guidance of a visual impression. In making the movements most of the muscles of the arm are involved, as are the external muscles of the eye and its mechanism of accommodation.”

The results of the J-D. form are summed up and presented in Table II, and the subsequent curves. As in the previous test there are no significant group variations shown. Both groups give practically the same type of performance. The central tendency and the variability of the two groups are practically identical. The mean time performance of the former group is 98.3 seconds (S.D. 4.453), of the latter group 98.6 seconds (S.D.

6.371). The mean number of contacts for the goiter group is 5.2 (S.D. 3.81) and for the non-goiter group 4.6 (S.D. 3.73) for the five daily practice periods. And as in the previous test, the reliability quotients also indicate that there are no significant differences between the groups.

A correct time performance in this test would be 102 seconds. A perfect score would be no contacts. Eleven out of the 103 in the goiter group finished the blank in 102 seconds, whereas none of the non-goiter group did. Two of the former group made no contacts in the five trials. One of these, Bar. finished 6 seconds too soon, the other, Wat., finished 7 seconds too soon. The eleven who made a perfect time score, with one exception, made fewer contacts than those who deviated in either direction from 102 seconds. Those showing perfect rhythm, with the exception of Odg. who made 18 contacts, made but one to five contacts, on the average. In the non-goiter group, there also appears to be a tendency for superior time and contact scores to be correlated. The curiously low time score of Hyd. (who finished 13 seconds too soon, on the average), is noteworthy. This subject was given from one to three extra practice periods in rhythm each of the five days, and each day she rushed through the test, making strokes just as rapidly as she could, and in rhythm to nods of her head, but in rhythm with the metronome, by chance only, if ever. Occasionally she stopped to make a period at the end of a line. This performance was consistent for each of the five days. This curious performance is easily explained on the basis of general inefficiency. She did poorly in all of the tests and also in her school work. She was diagnosed as having a hypo-secretion of the thyroid gland, and is a very short, thin, sallow, easily disturbed child, who cries on slight provocation. Figure A illustrates her performance in this test on the third day of practice

and at the close of her menstrual period, and is her best performance. Coarse tremor is shown in the third day practice sheet of Coc. (Figure B.)

The records for the five days for each subject, are variable and few subjects show a typical learning curve. The day to day fluctuations are, on the average, chaotic and do not show progressive improvement. Many made more contacts in the final trial than on the initial trial. Examples are the following:

Days	1	2	3	4	5
Contacts					
Ask.....	18	16	9	12	12
Hyd.....	20	20	19	26	27
Con.....	7	3	8	5	3
Cro.....	6	5	0	5	7
Flo.....	19	5	1	9	10
Nol.....	13	11	3	7	8

Only twice did typical learning curves appear as:

Days	1	2	3	4	5
Contacts					
Olm.....	8	5	4	2	1
Kel.....	7	4	3	2	0

and occasionally less typical ones as:

Days	1	2	3	4	5
Contacts					
Cro.....	3	1	1	1	0
Edw.....	4	3	3	1	1
Ode.....	6	4	3	1	1
Web.....	11	4	4	4	4
Oyl.....	8	7	7	4	4
Cas.....	11	5	5	5	4

TABLE II.—MOTOR COÖRDINATION TEST. JOHNSON-DUNLAP FORM

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subject	Average time in seconds	Average contacts
And.....	101	12	Alb.....	111	8
App.....	93	17	Bay.....	100	3
Ask.....	95	13	Bil.....	98	15
Atk.....	102	2	Bro-1.....	96	5
Aye.....	99	10	Bro-2.....	97	1
Bar.....	96	0	Bul.....	98	3
Ber.....	95	2	Car.....	97	6
Bla-1.....	98	6	Che.....	97	2
Bla-2.....	96	8	Cla.....	99	2
Boc.....	98	5	Cle.....	98	1
Boo.....	101	3	Cog.....	97	2
Bow.....	97	4	Col.....	99	5
Bro.....	102	2	Cor.....	97	2
Cha-1.....	96	6	Din.....	93	11
Cha-2.....	99	10	Fie.....	96	3
Clo.....	99	7	Fis.....	96	3
Coc.....	96	8	Gre.....	95	3
Con.....	103	5	Gri.....	105	9
Coo.....	102	1	Gro.....	113	5
Cro-1.....	95	5	Hal.....	103	3
Cro-2.....	109	1	Ham.....	96	4
Cro-3.....	96	6	Har.....	95	4
Cun.....	103	5	Hil.....	95	3
Dan-1.....	94	3	Hof.....	99	2
Dan-2.....	102	3	Ire-1.....	96	2
Dav-1.....	100	6	Ire-2.....	97	4
Dav-2.....	107	7	Kno.....	97	2
Dic.....	95	5	Kru.....	99	13
Die.....	95	3	Lee.....	98	5
Dun.....	102	5	Llo.....	98	20
Edw.....	95	2	May.....	135	5
Eic.....	96	8	Mui.....	97	4
Eve.....	98	5	Neu.....	98	10
Far.....	101	5	Oyl.....	96	6
Fie.....	95	4	Pow.....	96	1
Fin.....	102	3	Rad.....	95	5
Fle.....	95	2	Rob.....	105	3
Flo.....	97	9	Ros.....	95	5
Fre.....	106	2	Sew.....	96	1
Gat.....	97	12	Sne.....	97	6
Gri-1.....	101	3	Tho-1.....	95	3

TABLE II.—(Continued)

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subject	Average time in seconds	Average contacts
Gri-2.....	100	7	Tho-2.....	100	4
Ham.....	95	6	Tow.....	96	6
Har.....	99	4	Was-1.....	101	3
Hig.....	100	5	Was-2.....	96	6
Him.....	103	2	Wea.....	96	4
Hin.....	95	7	Web.....	95	3
Hip.....	101	4	Whi.....	99	2
Hug.....	100	3	Wie.....	98	5
Hyd.....	89	22	Wil.....	93	6
Jen-1.....	102	4	Wis.....	96	2
Jen-2.....	102	3			
Kel.....	96	4			
Klo.....	102	3			
Lag.....	95	4			
Lan.....	93	3			
Lay.....	100	10			
Lee.....	94	4			
Lew.....	103	7			
Lip.....	95	1			
Llo.....	101	5			
Lue.....	99	10			
Mar.....	95	2			
Mas.....	96	8			
Mcg.....	94	2			
Mig-1.....	94	16			
Mig-2.....	94	10			
Mil-1.....	101	4			
Mil-2.....	97	5			
Mil-3.....	101	5			
Mos.....	103	10			
Nol.....	93	9			
Ode.....	101	3			
Odg.....	102	18			
Olm.....	98	4			
Pha.....	95	1			
Ple.....	93	2			
Plu.....	102	3			
Poo.....	98	1			
Pre.....	100	4			
Pri.....	97	6			

TABLE II.—(Continued)

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subjects	Average time in seconds	Average contacts
Rei.....	97	3			
Ric.....	95	2			
Rob.....	96	3			
Rod.....	97	5			
Rut.....	100	3			
Sal-1.....	97	2			
Sal-2.....	95	3			
Sca.....	95	3			
Sch-1.....	96	8			
Sch-2.....	96	6			
Sho.....	99	12			
Sip.....	126	4			
Sto.....	97	4			
Str.....	96	5			
Ten.....	96	5			
Twi.....	104	2			
Wag.....	96	1			
Wal.....	94	5			
War.....	101	4			
Wat.....	95	0			
Web.....	94	5			
Wri.....	103	3			

Time		Time	
Number tested.....	103	Number tested.....	51
Total score.....	10,132	Total score.....	5,030
Mean.....	98.3 ± .2957	Mean.....	98.6 ± .6018
M.D.....	3.2	M.D.....	3.4
S.D.....	4.4530 ± .2563	S.D.....	6.3713 ± .4255
Range.....	89-126	Range.....	93-135
Difference in mean.....		.3 ± .6705	
D.....			
P.E.D.....		.45	
Difference in S.D.....		1.9183 ± .4519	
D.....			
P.E.D.....		.42	

TABLE II.—(Continued).

Contacts		Contacts	
Number tested.....	103	Number tested.....	51
Total score.....	544.2	Total score.....	236.35
Mean.....	$5.2 \pm .2535$	Mean.....	$4.63 \pm .3529$
M.D.....	2.7	M.D.....	2.61
S.D.....	$3.8167 \pm .1794$	S.D.....	$3.7369 \pm .2496$
Range.....	0-22	Range.....	1-20
Difference in mean.....		$.57 \pm .4345$	
D.			
P.E.D.....		1.31	
Difference in S.D.....		$.0798 \pm .3074$	
D.			
P.E.D.....		.26	

Inspection of the individual scores is again instructive. It shows that the largest number of contacts was made by the subjects who showed tremor and had a high pulse rate. And. who made, on the average, 12 contacts had a pulse rate of 118 and was being treated for thyroid misfunction. Ask. and all other subjects of the goiter group, excepting Aye., whose contact score amounted to 10 or more had a high pulse rate and were under a physician's care for thyroid disturbance. In the non-goiter group the number of contacts made was in proportion to the age or to nervous stability of the individual.

When the goiter group is redistributed according to diagnoses no significant variations are seen to occur between groups. The mean times required by the large, medium, and small enlargement groups, and the adenomata group, are 97.8, 98.5, 99.5, and 96.2 seconds respectively, while the average contacts for the five trials for these groups are 5.2, 5.4, 5.1, and 5.5 respectively.

All groups have about the same variability for both time and contact. A sigma of 5.8 for time for the slight group as compared with sigmas of 2.2, 3.1, and 2.7 for the large, medium, and adenomata groups suggests that the slight group is slightly more variable than the others.

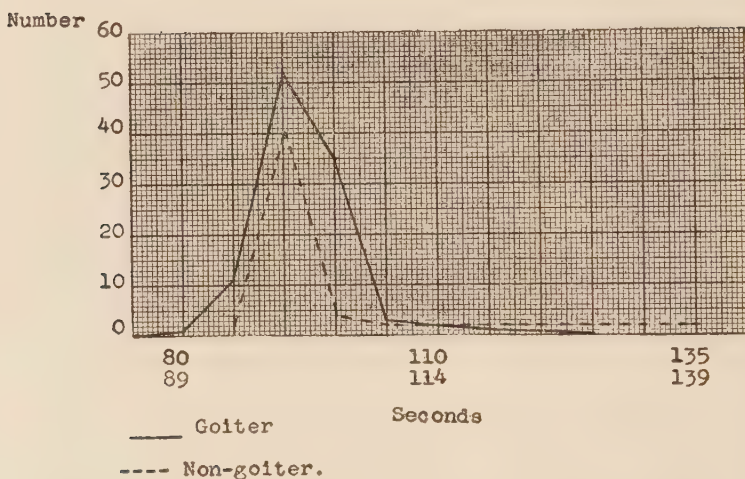


FIG. 4.—Distribution of time scores. Motor coördination test. J-D form.

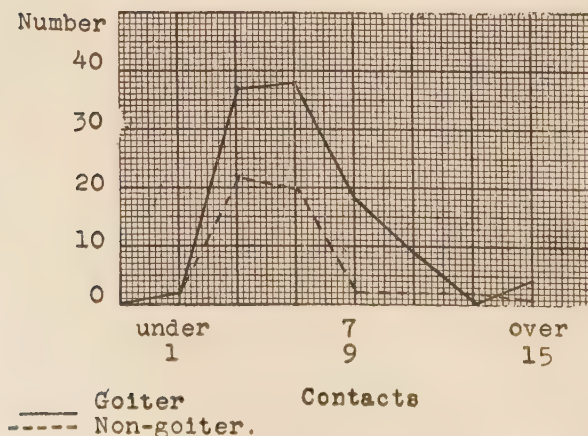


FIG. 5.—Distribution of contact scores. Coördination test. J-D form.

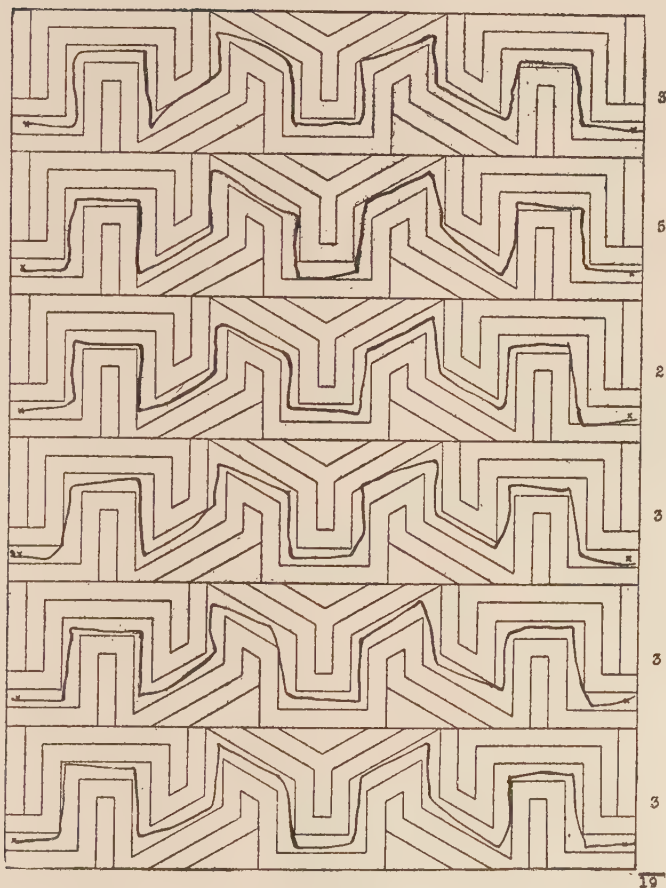


FIG. A.—Sub. Hyd. 6/11/24. 1'24". In time, if ever, only by chance.

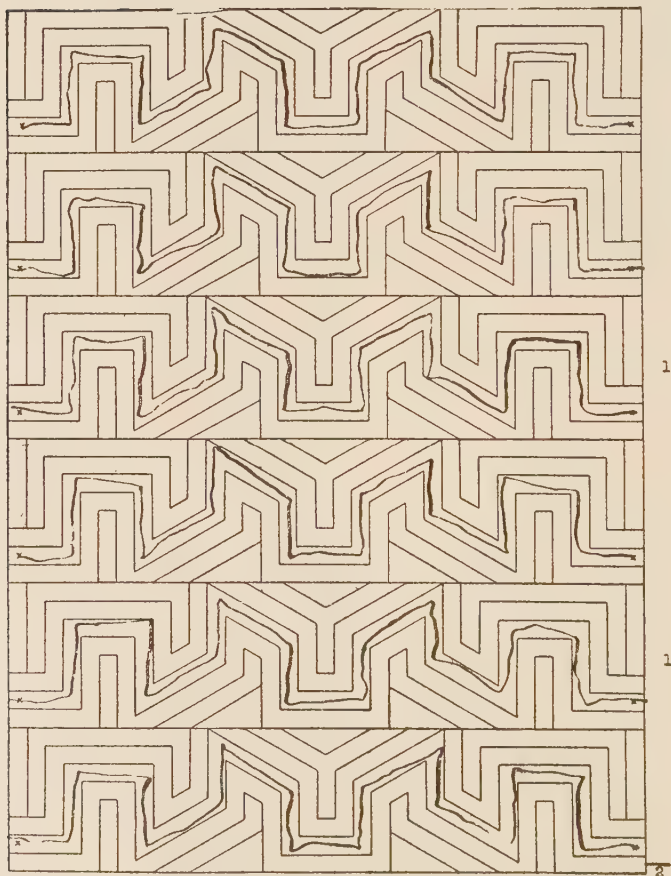


FIG. B.—Sub. Coc. 2/29/24. 1'34".

The reliability quotients for the slight-large, slight-medium, and slight-adenoma also indicate a true difference.

The large group, it will be noted, includes more of the subjects than do any of the other sub-groups, and it also includes the majority of the subjects who show tremor and tachycardia.

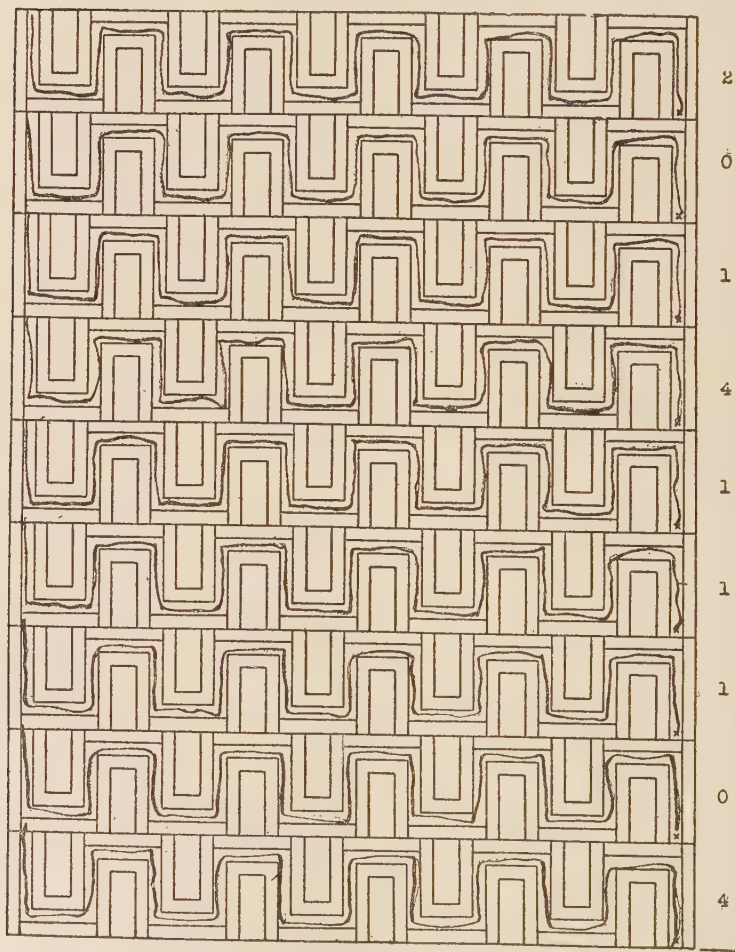


FIG. C.—Coördination test (Dunlap). Johns Hopkins Series. Sub.
Bar. 2/28/24. 2'57".

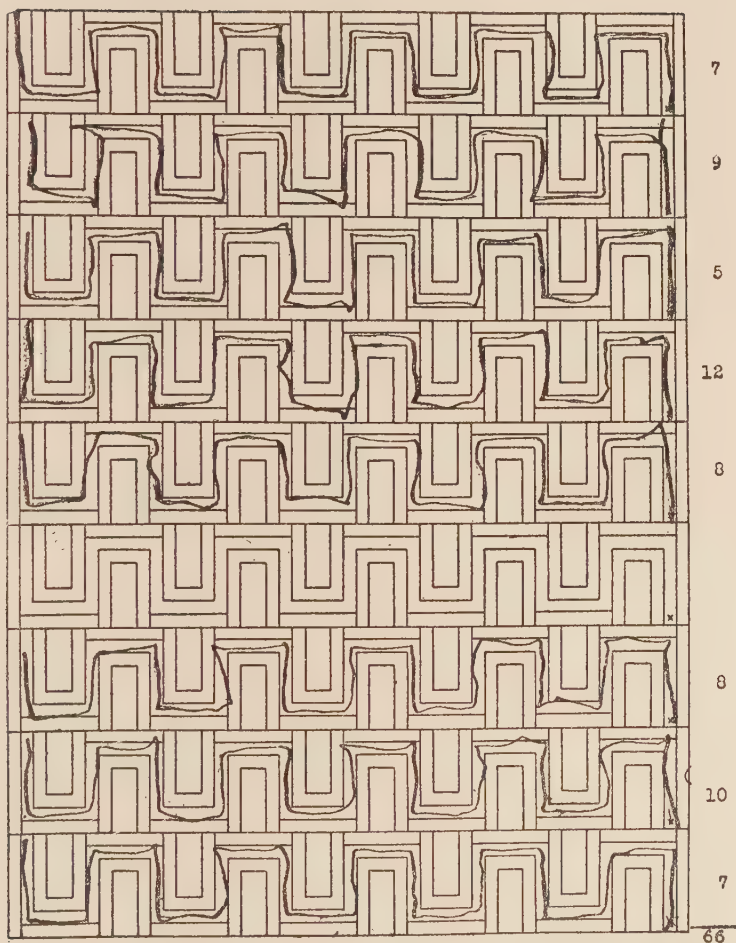


FIG. D.—Coördination test (Dunlap). Johns Hopkins Series. Sub. Coc. 2/29/24. 2'35". Lost one count by going to line below and then back to correct line. Has an intermittent fine tremor of left hand especially when pressed on table.

TABLE IIa.—MOTOR COÖRDINATION TEST. JOHNSON-DUNLAP FORM. THYROID SUB-GROUPS

Large thyroid enlargement			Medium thyroid enlargement			Slight thyroid enlargement			Adenomata		
Subject	Aver- age time secs.	Aver- age con- tacts	Subject	Aver- age time secs.	Aver- age con- tacts	Subject	Aver- age time secs.	Aver- age con- tacts	Subject	Aver- age time secs.	Aver- age con- tacts
Boc.....	98	5	Ask.....	95	13	And.....	101	12	Atk.....	102	2
Cro-3.....	96	6	Bow.....	97	4	App.....	93	17	Bar.....	96	0
Dan-2.....	102	3	Cha-1.....	96	6	Aye.....	99	10	Coc.....	96	8
Dic.....	95	5	Con.....	103	5	Ber.....	95	2	Die.....	95	3
Flo.....	97	9	Dan-1.....	94	3	Bla-1.....	98	6	Dun.....	102	5
Gat.....	97	12	Day-1.....	100	6	Bla-2.....	96	8	Hin.....	95	7
Hig.....	100	5	Eve.....	98	5	Boo.....	101	3	Hip.....	101	4
Kel.....	96	4	Far.....	101	5	Bro.....	102	2	Lag.....	95	4
Lip.....	95	1	Fin.....	102	3	Cha-2.....	99	10	Lee.....	96	4
Lio.....	101	5	Fle.....	95	2	Clo.....	99	7	Mas.....	94	8
Mil-3.....	101	5	Gri-1.....	101	3	Coo.....	102	1	Mig-1.....	94	16
Pha.....	95	1	Him.....	103	2	Cro-1.....	95	5	Mig-2.....	94	10
Poo.....	98	1	Jen-2.....	102	3	Cro-2.....	109	1	Nol.....	93	9
Sho.....	99	12	Lan.....	93	3	Cun.....	103	5	Olm.....	98	4
Sto.....	97	4	Lay.....	100	10	Dav-2.....	107	7	Ple.....	93	2
			Luc.....	99	10	Edw.....	95	8	Rel.....	97	6
			Mcg.....	94	2	Eic.....	96	2	Str.....	96	5
			Mil-2.....	97	5	Fie.....	95	4	Web.....	94	5
			Mos.....	103	10	Fre.....	106	2			
			Ode.....	101	3	Gri-2.....	100	7			
			Odg.....	102	18	Ham.....	95	6			
			Rob.....	96	3	Har.....	99	4			
			Rod.....	97	5	Hug.....	100	3			
			Rut.....	100	3	Hyd.....	89	22			
			Sal-2.....	95	3	Jen-1.....	102	4			
			Sch-1.....	96	8	Klo.....	102	3			
			Sch-2.....	96	5	Lew.....	103	7			
			Ten.....	96	5	Mar.....	95	2			
			Tw.....	104	2	Mil-1.....	101	4			

TABLE IIb.—DIFFERENCES IN CONSTANTS FOR GOITER SUB-GROUPS
IN MOTOR COÖRDINATION TEST—JOHNSON-DUNLAP FORM

Groups compared	Time			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	.7 ± .5595	1.25	0.9232 ± .3956	2.33
Large-slight.....	1.7 ± .7395	2.30	3.6169 ± .5229	6.92
Large-adenoma.....	1.6 ± .5742	2.79	0.4493 ± .3848	1.17
Medium-slight.....	1.0 ± .7430	1.35	2.6937 ± .5248	5.13
Medium-adenoma.....	2.3 ± .5779	3.98	0.4739 ± .3874	1.22
Slight-adenoma.....	3.3 ± .7535	4.38	3.1676 ± .5167	6.13
	Contacts			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	.2 ±	<1	0.6101 ±	<1
Large-slight.....	.1 ±	<1	1.0748 ± .5067	2.12
Large-adenoma.....	.3 ±	<1	0.3709 ±	<1
Medium-slight.....	.3 ±	<1	0.4647 ± .4647	1.00
Medium-adenoma.....	.1 ±	<1	0.2392 ±	<1
Slight-adenoma.....	.4 ±	<1	0.7039 ± .5043	1.40

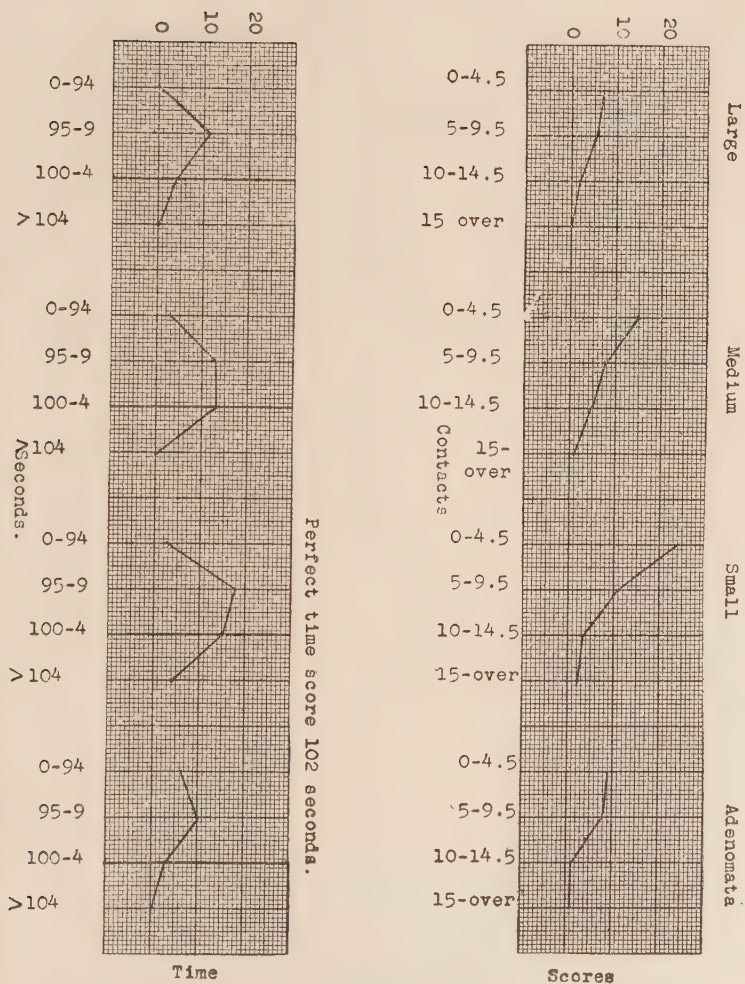


FIG. 6.—Coordination test. Johnson-Dunlap form. Distribution of time and contact scores in goiter sub-groups.

TABLE III.—MOTOR COÖRDINATION TEST. DUNLAP FORM

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subject	Average time in seconds	Average contacts
And.....	179	54	Alb.....	184	60
App.....	168	99	Bay.....	184	63
Ask.....	169	91	Bil.....	177	109
Atk.....	190	48	Bro-1.....	178	29
Aye.....	186	71	Bro-2.....	180	36
Bar.....	173	12	Bul.....	182	41
Ber.....	176	37	Car.....	188	76
Bla-1.....	195	48	Che.....	188	25
Bla-2.....	175	62	Cla.....	200	36
Boc.....	178	55	Cle.....	176	21
Boo.....	185	26	Cog.....	180	42
Bow.....	178	60	Col.....	181	86
Bro.....	178	46	Cor.....	180	45
Cha-1.....	187	63	Din.....	171	123
Cha-2.....	180	110	Fie.....	165	37
Clo.....	179	49	Fis.....	178	56
Coc.....	165	61	Gre.....	177	52
Con.....	188	78	Gri.....	193	81
Coo.....	189	32	Gro.....	182	54
Cro-1.....	173	63	Hal.....	189	45
Cro-2.....	189	27	Ham.....	166	42
Cro-3.....	177	66	Har.....	178	44
Cun.....	184	52	Hil.....	177	38
Dan-1.....	165	51	Hof.....	206	61
Dan-2.....	189	30	Ire-1.....	177	24
Day-1.....	185	37	Ire-2.....	179	33
Day-2.....	198	68	Kno.....	180	52
Dic.....	178	37	Kru.....	169	108
Die.....	175	34	Lee.....	183	57
Dun.....	170	65	Lew.....	155	46
Edw.....	176	55	Llo.....	179	126
Eic.....	177	70	May.....	202	68
Eve.....	187	55	Mui.....	180	41
Far.....	188	54	Neu.....	170	104
Fie.....	176	69	Oyl.....	173	53
Fin.....	188	41	Pow.....	175	21
Fle.....	178	51	Rad.....	157	64
Flo.....	181	73	Rob.....	170	50
Fre.....	183	58	Ros.....	172	70
Gat.....	185	58	Sne.....	176	58
Gri-1.....	187	37	Tho-1.....	178	35

TABLE III.—(Continued)

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subject	Average time in seconds	Average contacts
Gri-2.....	183	41	Tho-2.....	178	34
Ham.....	176	62	Tow.....	176	70
Har.....	185	55	Was-1.....	189	43
Hig.....	186	54	Was-2.....	174	86
Him.....	194	50	Wea.....	176	52
Hin.....	175	78	Web.....	176	43
Hip.....	200	42	Whi.....	178	50
Hug.....	185	32	Wie.....	176	81
Hyd.....	153	108	Wil.....	172	85
Jen-1.....	189	51	Wis.....	165	38
Jen-2.....	189	62			
Kel.....	177	59			
Klo.....	190	55			
Lag.....	178	25			
Lan.....	159	46			
Lay.....	186	84			
Lee.....	174	57			
Lew.....	187	64			
Lip.....	155	32			
Llo.....	188	59			
Luc.....	174	63			
Mar.....	175	47			
Mas.....	161	52			
Mcg.....	177	31			
Mig-1.....	171	88			
Mig-2.....	178	70			
Mil-1.....	170	65			
Mil-2.....	188	47			
Mil-3.....	187	55			
Mos.....	184	54			
Nol.....	169	73			
Ode.....	161	40			
Odg.....	184	89			
Olm.....	186	52			
Pha.....	178	22			
Ple.....	160	30			
Plu.....	194	64			
Poo.....	182	25			
Pre.....	178	53			

TABLE III.—(Continued)

Goiter			Non-goiter		
Subject	Average time in seconds	Average contacts	Subject	Average time in seconds	Average contacts
Pri.....	177	61			
Rei.....	180	39			
Ric.....	178	42			
Rob.....	175	30			
Rod.....	177	51			
Rut.....	186	55			
Sal-1.....	179	50			
Sal-2.....	173	62			
Sca.....	178	65			
Sch-1.....	169	91			
Sch-2.....	162	45			
Sho.....	189	97			
Sip.....	188	50			
Sto.....	155	82			
Str.....	173	44			
Ten.....	177	98			
Twl.....	191	34			
Wag.....	187	67			
Wal.....	169	70			
War.....	188	59			
Wat.....	179	20			
Web.....	176	72			
Wri.....	189	54			

Time		Time	
Number tested.....	103	Number tested.....	51
Total score.....	18468	Total score.....	9095
Mean.....	179.3 ± .6213	Mean.....	178.3 ± .8896
M.D.....	7.4	M.D.....	6.4
S.D.....	9.3490 ± .439	S.D.....	9.4198 ± .6291
Range.....	153-200	Range.....	155-206
Difference in mean.....		1.0 ± 1.0850	
D.....		.9216	
D.P.E.....		.0708 ± .7671	
Difference in S.D.....		.0922	
D.....			
P.E.D.....			

TABLE III.—(Continued)

Contacts		Contacts	
Number tested.....	103	Number tested.....	51
Total score.....	5726	Total score.....	2895
Mean.....	55.59 ± 1.2804	Mean.....	56.8 ± 2.3829
M.D.....	14.6	M.D.....	19.6
S.D.....	$19.2663 \pm .9054$	S.D.....	25.2202 ± 1.6843
Range.....	12-110	Range.....	21-126
Difference in mean.....		1.2 ± 2.7043	
D.....			
P.E.D.....		.4437	
Difference in S.D.....		5.9539 ± 1.9122	
D.....			
P.E.D.....		3.1136	

2. *Dunlap Form.*—The results of this test are presented in table III and figures 7 and 8. The statistical analyses show no significant differences in performance between the groups. Any variation that occurs is a purely chance one and not one due to a difference in the constitution of the groups.

This sheet should be completed in 189 seconds, if no time is lost within or between the lines and if no "double stepping" occurs. Seven of the goiterous subjects completed the sheet on schedule time while two of the non-goiter group did. The mean time for the goiter group is 179.3 seconds, that for the non-goiter is 178.3 seconds, and there is very little difference in the range of the contacts for the two groups, being 12 to 110 for the former and 21 to 126 for the latter. The mean number of contacts for the former group is 55.5, for the latter 56.7. Compared in terms of variability the sigmas for the time scores overlap; the non-goiter group shows a larger sigma for the contact scores than the goiter group, indicating a comparatively greater variability for this group.

A consideration of individual scores shows that in the goiter group Bar. made the fewest contacts, on the average, of any of the 103 subjects tested, but she completed

the sheet 16 seconds too soon. In the former sheet she made no contacts but finished 6 seconds too soon. Whether her superior score is due to superior coördination and motor control or to the added speed of movement which tends to decrease the possible chances for contact cannot be determined. Once she went from line 1 to

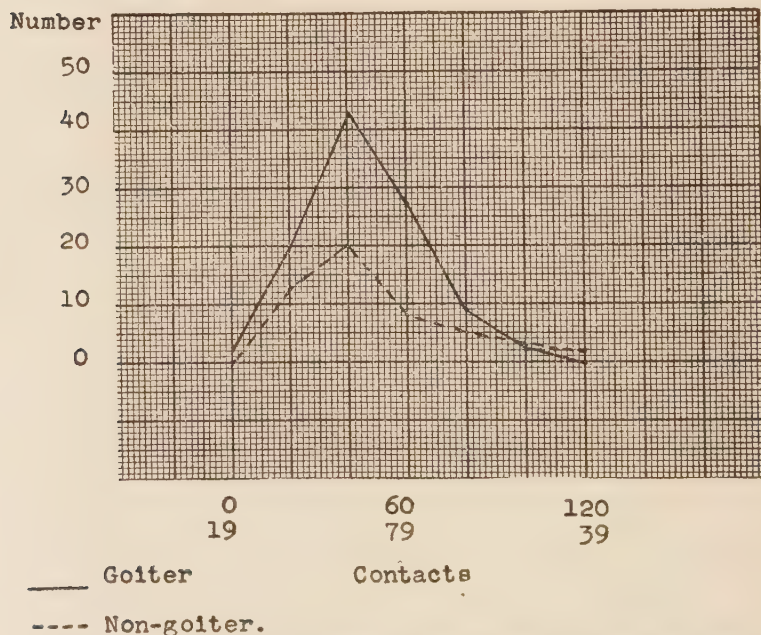


FIG. 7.—Distribution of contacts. Coördination test. Dunlap form.

line 3, then noting her error, after completing line 3, returned to line 2 and from 2 passed to 4. In this procedure she lost time which she attempted to make up by making two strokes to one beat and having established this double rhythm, tended to continue it and so completed the sheet too soon. Fig. C represents Bar.'s best performance. The tendency to pass from

line 1 to line 3, was noted in a number of individuals and may be due to the fact that passing from line 1 to line 3 in this test involves an amplitude of movement similar to that of passing from line 1 to line 2 in the

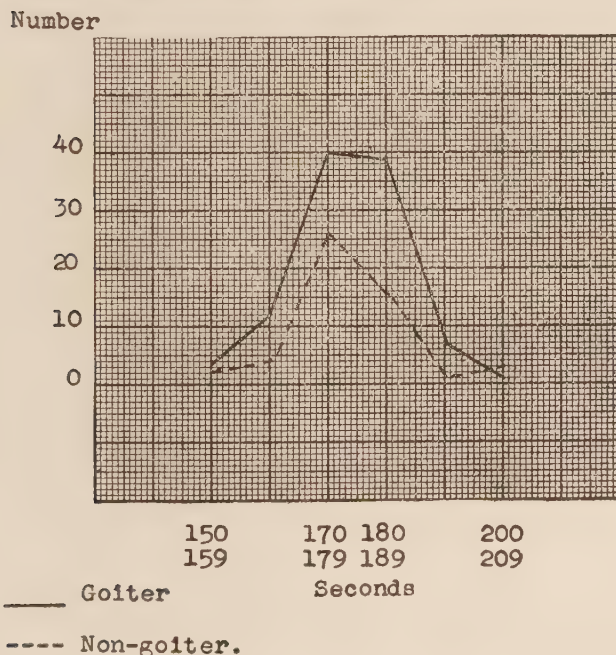


FIG. 8.—Distribution of time scores. Coördination test. Dunlap form.

previous test, and the habit having been formed in the first test with the more simple sheet, tends to be transferred to the second test with the more complex sheet. This raises the question as to whether it is advisable to use the two forms in succession. The time score of several individuals fell considerably below the 189 seconds because a complete line was omitted as a result

of this tendency. One of the poorest scores is that of Coc. whose poorly coördinated movements and whose tremor are clearly shown in Fig. D, which is a typical performance. And as in the former test the performance of Hyd. is the poorest of the group. Here again she hastened through the sheet at a rhythm all her own, completing her sheets, on the average, 36 seconds too soon.

In this sheet, as in the J-D form there were very few typical learning curves. The day by day fluctuations in score tend to be chaotic. The following are representative:

Days	1	2	3	4	5
Contacts					
Ask.....	83	98	83	90	103
Cha.....	104	124	114	117	90
Hyd.....	106	113	97	111	114

There are but four typical learning curves in the one hundred and three records. These are:

Days	1	2	3	4	5
Contacts					
Edw.....	82	55	54	45	38
Ham.....	84	65	62	53	48
Sal.....	56	56	54	45	37
Sch.....	103	97	85	77	

The failure, in these tests, for learning to occur is probably due to the fact that the movement involved in tracing the path is one that has been more or less thoroughly learned in the movement involved in writing. And the guess is offered that a high correlation would be found between excellence in chirography and fewness

of contacts in these tests. Had the tracing been done from right to left instead of from left to right, learning probably would have occurred as a more or less unlearned movement would have been involved. The interplay of interest, effort, and volition is naturally involved and the low time scores may be due to any or all three of these factors. Some of the failures in rhythm may be attributed to the fact that, in two of the schools, the orchestra was often playing in the assembly room which adjoined the room in which the tests were given. This introduced a confusion of rhythm. But, one might argue, had the interest been keen the attention would have been focused on the test to the oblivion of the music outside.

Here again one must regret the lack of figures for comparison. No similar studies have been reported excepting that of Dorcus quoted above. He reports for the J-D form, for his athletic group, an average of 13.9 contracts per individual, and for the non-athletic group an average of 16.6 contacts. For the D. form his average for the former group is 39 contacts, and for the latter 41 contacts per individual. His figures represent the average of two trials whereas the figures in this study represent the average for five trials. Further, his subjects may be assumed to be older than the subjects of this study—though he gives no clue regarding the age of his subjects beyond the statement that they are college students—which may account, in part, for the superior scores made by them.

When the goiter group is subdivided into four subgroups no significant inter-group variations are found. Tables IIIa and IIIb and the following curves give a summarized form of the data for these groups. The mean time scores for the large, medium, and small enlargement groups, and the adenomata group, are 179, 179.2, 181.1,

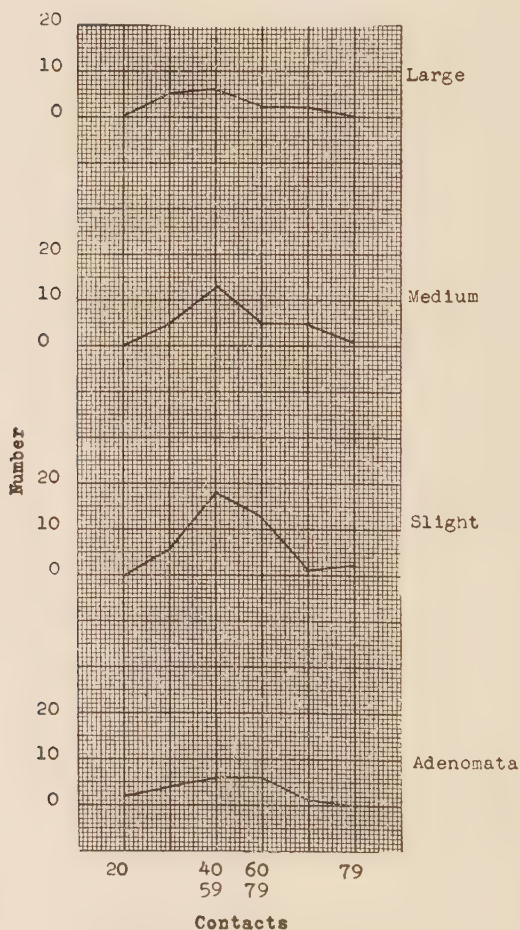


FIG. 9.—Goiter sub-groups. Coördination test. Dunlap form.
Distribution of contact scores.

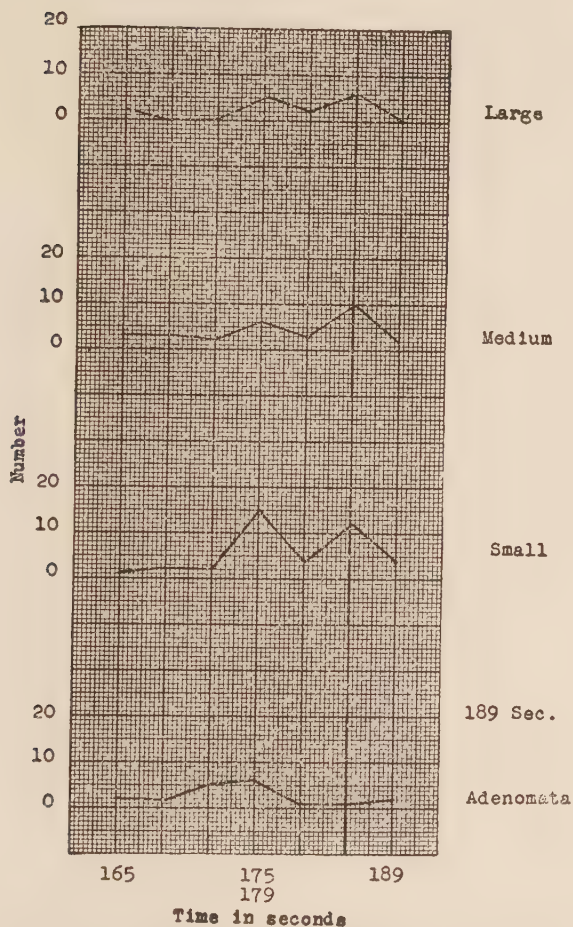


FIG. 10.—Goiter sub-groups. Coördination test. Dunlap form.
Distribution of time scores.

TABLE IIIa.—MOTOR COÖRDINATION TEST. DUNLAP FORM. THYROID SUB-GROUPS

Large thyroid enlargement			Medium thyroid enlargement			Slight thyroid enlargement			Adenomata		
Subject	Aver- age time sec- onds	Aver- age con- tacts	Subject	Aver- age time sec- onds	Aver- age con- tacts	Subject	Aver- age time sec- onds	Aver- age con- tacts	Subject	Aver- age time sec- onds	Aver- age con- tacts
Boo.....	178	55	Ask.....	169	91	And.....	179	54	Atk.....	190	48
Cro-3.....	177	66	Bow.....	187	60	App.....	168	99	Bar.....	173	12
Dan-2.....	189	30	Cha-1.....	187	63	Aye.....	186	71	Coc.....	165	61
Die.....	178	37	Con.....	188	78	Ber.....	176	37	Die.....	175	34
Flo.....	181	73	Dan-1.....	165	51	Bla-1.....	195	48	Dun.....	170	65
Gat.....	185	58	Dav-1.....	185	37	Bla-2.....	175	62	Hin.....	175	78
Hug.....	186	54	Eve.....	187	55	Boo.....	185	26	Hin.....	200	42
Kel.....	177	59	Far.....	188	46	Bro.....	178	46	Lag.....	178	25
Lip.....	155	32	Fin.....	188	41	Cha-2.....	180	110	Lee.....	174	57
Lio.....	188	59	Fle.....	178	51	Clo.....	179	49	Mas.....	161	52
Mil-3.....	187	55	Gri-1.....	187	37	Coc.....	189	32	Mig-1.....	171	88
Pha.....	178	22	Him.....	194	50	Cro-1.....	173	63	Mig-2.....	178	70
Poo.....	182	25	Jen-2.....	189	62	Cro-2.....	189	27	Nol.....	169	73
Sho.....	189	97	Lan.....	159	46	Cun.....	184	52	Olm.....	186	52
Sto.....	155	82	Lay.....	186	84	Dav-2.....	198	68	Pie.....	160	30
			Luc.....	174	63	Edw.....	176	55	Pri.....	177	61
			Mcg.....	177	31	Eic.....	177	70	Rel.....	180	39
			Mil-2.....	188	47	Fie.....	176	69	Str.....	173	44
			Mos.....	184	54	Fre.....	183	58	Web.....	176	72
			Ode.....	161	40	Gri-2.....	183	41			
			Odg.....	184	89	Ham.....	176	62			
			Rob.....	175	30	Har.....	185	55			
			Rod.....	177	51	Hug.....	185	32			
			Rut.....	186	55	Hyd.....	153	108			
			Sal-2.....	173	62	Jen-1.....	189	51			
			Sch-1.....	169	91	Klo.....	190	55			
			Sch-2.....	162	45	Lew.....	187	64			
			Ten.....	177	98	Mar.....	175	47			

TABLE IIIb.—DIFFERENCES IN CONSTANTS FOR GOITER SUB-GROUPS
IN MOTOR COÖRDINATION TEST—DUNLAP FORM

Groups compared	Time			
	Diff. in M.	D. P.E.D.	Diff. in S.D.	D. P.E.D.
Large-medium.....	.2±	<1	0.8715±	<1
Large-slight.....	2.1±	<1	2.0149±1.4206	1.42
Large-adenoma.....	3.7±2.0092	1.84	1.1018±	<1
Medium-slight.....	1.9±1.4826	1.28	1.1434±1.0482	1.09
Medium-adenoma.....	3.9±1.8588	2.10	0.2303±	<1
Slight-adenoma.....	5.8±1.6841	3.44	0.9131±	<1

	Contacts			
	Diff. in M.	D. P.E.D.	Diff. in S.D.	D. P.E.D.
Large-medium.....	5.0±4.4491	1.12	0.0978±	<1
Large-slight.....	3.2±	<1	1.8805±	<1
Large-adenoma.....	.6±4.6792	<1	1.5959±3.3086	<1
Medium-slight.....	1.8±	<1	1.7827±	<1
Medium-adenoma.....	5.6±3.9386	1.4218	1.4981±2.7849	<1
Slight-adenoma.....	3.8±3.5869	1.059	0.2846±2.5362	<1

and 175.3 respectively, while the mean contact score for the same groups are 53.4, 58.4, 56.6, and 55.5. The variability for contacts as shown by the standard deviation is greater than that for time, but as measured by the mean and the standard deviation, there is no difference in superiority or variability between any sub-groups and either group as a whole. The reliability quotients are also indicative of a lack of difference other than that due to chance.

COMPARISON OF THE GOITER AND NON-GOITER GROUPS IN THE DYNAMOMETER TEST

Advocates for and against the use of the dynamometer as a measure of fatigue and muscular strength are numerous. Competent physiologists and psychologists have arrayed themselves on both sides and whichever view one takes one finds oneself in excellent company. Franz

objects first, that the movement of grasping the dynamometer is not a simple one and secondly that the contractions permitted by the instrument are not maximal in extent. The first objection is worthy of consideration, the second, as Franz agrees, is of little value.

The movement of grasping the dynamometer is a complex one involving the use of many muscles, and is the total effect of all stimuli acting synchronously. The result is a measure of muscle strength and of attitude, showing the degree of retention and relaxation of which the individual is capable as well as his habits of mind. In the present study, in an attempt to get each subject to exert her maximal effort, the records made were reported each day, for each subject, which aroused a spirit of keen competition and served as an incentive to the best effort. This test was the most popular, of the four, with almost all subjects.

A summary of the results of the test are given in Tables IV and IVa and the following curves, which reveal no significant differences in performance between the groups. The means with the S.Ds. as a measure of variability are given for the gross score, for the average of trials 1 and 2, and trials 19 and 20 for both hands. For the goiter group the means for the right hand are 28.3, 28.2, and 28.9, for the gross score, average of 1 and 2, and average of 19 and 20 respectively. These means for the non-goiter group are 29.5, 29.4, and 30.2. For the left hand, in the goiter group the mean of twenty trials is 25.6, that of the average of 1 and 2 is 25.9 as is also the average of 19 and 20. For the non-goiter group these means are 26.7, 26.9 and 27.1. In both hands the initial total efficiency (ave. of 1 and 2) and the final total efficiency scores (ave. of 19 and 20) are both slightly higher, but not significantly so, for the non-goiter group. Compared in terms of variability the sigmas show that one

TABLE IV.—DYNAMOMETER TEST. RIGHT HAND

Goiter				Non-goiter			
Subject	Average 20 trials	Average 1 & 2	Average 19 & 20	Subject	Average 20 trials	Average 1 & 2	Average 19 & 20
And.....	22	23	23	Alb.....	23	24	23
App.....	23	21	25	Bay.....	33	32	34
Ask.....	23	21	23	Bil.....	26	27	25
Atk.....	29	30	28	Bro-1.....	29	30	30
Aye.....	31	31	30	Bro-2.....	23	24	22
Bar.....	24	23	25	Bul.....	29	30	30
Ber.....	37	38	36	Car.....	30	32	31
Bla-1.....	33	31	35	Che.....	24	25	26
Bla-2.....	31	32	31	Cla.....	31	30	32
Boc.....	27	26	27	Cle.....	28	28	29
Boo.....	24	25	25	Cog.....	30	29	31
Bow.....	28	28	28	Col.....	28	28	28
Bro.....	31	29	31	Cor.....	29	27	29
Cha-1.....	27	27	27	Din.....	25	25	25
Cha-2.....	23	24	23	Fie.....	33	33	34
Clo.....	33	32	31	Fis.....	28	29	30
Coc.....	20	20	21	Gre.....	28	30	28
Con.....	29	30	29	Gri.....	29	27	31
Coo.....	28	25	29	Gro.....	31	29	30
Cro-1.....	36	34	38	Hal.....	34	35	37
Cro-2.....	32	31	34	Ham.....	33	33	34
Cro-3.....	32	32	32	Har.....	32	32	33
Cun.....	32	36	32	Hil.....	33	31	36
Dan-1.....	26	24	27	Hof.....	35	32	37
Dan-2.....	34	35	34	Ire-1.....	27	28	26
Dav-1.....	26	26	27	Ire-2.....	30	29	30
Dav-2.....	31	29	32	Knc.....	33	31	33
Die.....	31	29	32	Kru.....	23	23	25
Die.....	33	34	36	Lee.....	30	31	32
Dun.....	31	31	29	Llo.....	29	29	30
Edw.....	28	29	30	May.....	24	22	23
Eic.....	29	29	30	Mui.....	28	25	29
Eve.....	27	24	27	Neu.....	29	30	29
Far.....	31	33	31	Oyl.....	28	27	29
Fie.....	31	30	32	Pow.....	35	36	39
Fin.....	32	31	34	Rob.....	31	30	32
Fle.....	31	31	32	Rod.....	28	27	30
Flo.....	22	23	21	Ros.....	31	31	31
Fre.....	23	20	20	Sew.....	37	39	38
Gat.....	23	26	23	Sne.....	32	32	32
Gri-1.....	27	26	26	Tho-1.....	34	32	36
Gri-2.....	23	22	23	Tho-2.....	33	37	34
Ham.....	28	28	28	Tow.....	31	31	30
Har.....	30	31	33	Was-1.....	36	39	34
Hig.....	28	31	32	Was-2.....	27	27	27
Him.....	28	30	28	Wea.....	27	26	26
Hin.....	27	27	26	Web.....	27	28	26
Hip.....	26	26	28	Whi.....	23	22	24
Hug.....	29	28	30	Wie.....	32	33	34
Hyd.....	21	19	22	Wil.....	30	31	31
Jen-1.....	38	38	40	Wis.....	31	28	32
Jen-2.....	23	23	24				
Kel.....	29	28	30				
Klo.....	33	33	35				

TABLE IV.—(Continued)

Goiter				Non-goiter			
Subject	Average 20 trials	Average 1 & 2	Average 19 & 20	Subject	Average 20 trials	Average 1 & 2	Average 19 & 20
Lag.....	40	42	40				
Lan.....	22	24	22				
Lay.....	24	24	24				
Lee.....	27	27	28				
Lew.....	27	27	26				
Lip.....	33	34	33				
Llo.....	28	28	28				
Luc.....	30	29	31				
Mar.....	32	32	32				
Mas.....	26	27	28				
Mcg.....	24	22	25				
Mig-1.....	24	23	22				
Mig-2.....	23	24	23				
Mil-1.....	35	33	35				
Mil-2.....	28	28	27				
Mil-3.....	32	33	32				
Mos.....	24	24	23				
Nol.....	35	35	36				
Ode.....	31	30	32				
Odg.....	31	32	33				
Olm.....	33	34	35				
Pha.....	29	27	30				
Ple.....	26	26	27				
Plu.....	24	30	29				
Poo.....	29	29	29				
Pre.....	33	33	33				
Pri.....	29	27	29				
Rei.....	28	25	28				
Ric.....	29	29	30				
Rob.....	30	30	31				
Rod.....	28	28	29				
Rut.....	31	28	31				
Sal-1.....	29	30	30				
Sal-2.....	25	26	26				
Sca.....	19	19	18				
Sch-1.....	33	31	35				
Sch-2.....	25	22	25				
Sho.....	30	30	29				
Sip.....	22	22	25				
Sto.....	29	29	29				
Str.....	35	35	35				
Ten.....	32	33	34				
Twl.....	26	26	27				
Wag.....	25	25	25				
Wal.....	29	31	29				
War.....	31	33	32				
Wat.....	29	30	28				
Web.....	24	24	25				
Wri.....	26	27	26				

106 *GOITEROUS AND NON-GOITEROUS GIRLS*

Average 20 trials		Average 20 trials	
Number tested.....	103	Number tested.....	51
Total score.....	2926.45	Total score.....	1508.5
Mean.....	28.41 ± .2733	Mean.....	29.5 ± .3269
M.D.....	3.32	M.D.....	2.8
S.D.....	4.1092 ± .1931	S.D.....	3.4605 ± .2313
Range.....	19-40	Range.....	23-37

Difference in mean.....	1.09 ± .4260
D.....	
P.E.D.....	2.55
Difference in S.D.....	.6487 ± .3013
D.....	
P.E.D.....	2.15

Average 1 & 2		Average 1 & 2	
Number tested.....	103	Number tested.....	51
Total score.....	2912.3	Total score.....	1501.8
Mean.....	28.2 ± .2883	Mean.....	29.4 ± .3579
M.D.....	3.4	M.D.....	2.8
S.D.....	4.3414 ± .2040	S.D.....	3.7898 ± .2531
Range.....	19-42	Range.....	22-39

Difference in mean.....	1.2 ± .4488
D.....	
P.E.D.....	2.67
Difference in S.D.....	.5516 ± .3251
D.....	
P.E.D.....	1.70

Average 19 & 20		Average 19 & 20	
Number tested.....	103	Number tested.....	51
Total score.....	2978.2	Total score.....	1543.3
Mean.....	28.9 ± .2906	Mean.....	30.2 ± .3716
M.D.....	3.5	M.D.....	3.0
S.D.....	4.3764 ± .2057	S.D.....	3.9345 ± .2628
Range.....	18-40	Range.....	22-39

Difference in mean.....	1.3 ± .4717
D.....	
P.E.D.....	2.76
Difference in S.D.....	.4419 ± .3337
D.....	
P.E.D.....	1.32

TABLE IVa.—DYNAMOMETER TEST. LEFT HAND

Goiter				Non-goiter			
Subject	Average 20 trials	Average 1 & 2	Average 19 & 20	Subject	Average 20 trials	Average 1 & 2	Average 19 & 20
And.....	22	21	21	Alb.....	25	25	25
App.....	19	21	21	Bay.....	29	28	29
Ask.....	19	20	19	Bil.....	24	26	22
Atk.....	27	27	27	Bro-1.....	24	24	24
Aye.....	28	29	28	Bro-2.....	21	23	21
Bar.....	23	22	24	Bul.....	26	25	26
Ber.....	29	33	32	Car.....	29	32	31
Bla-1.....	27	27	28	Che.....	23	22	24
Bla-2.....	29	29	30	Cla.....	32	30	32
Boc.....	27	26	28	Cle.....	28	27	29
Boo.....	23	27	23	Cog.....	26	25	25
Bow.....	23	23	24	Col.....	20	22	20
Bro.....	29	27	29	Cor.....	25	25	24
Cha-1.....	25	25	26	Din.....	26	26	25
Cha-2.....	23	23	23	Fie.....	31	31	30
Clo.....	25	28	24	Fis.....	26	27	26
Coc.....	18	18	18	Gre.....	26	27	26
Con.....	23	25	24	Gri.....	28	28	28
Coo.....	25	25	26	Gro.....	28	28	28
Cro-1.....	30	33	33	Hal.....	31	30	32
Cro-2.....	29	30	28	Ham.....	28	28	29
Cro-3.....	30	32	30	Har.....	27	27	27
Cun.....	28	30	27	Hil.....	30	27	32
Dan-1.....	26	24	27	Hof.....	29	28	31
Dan-2.....	31	30	32	Ire-1.....	26	27	24
Dav-1.....	25	24	25	Ire-2.....	28	27	27
Dav-2.....	26	25	26	Kno.....	31	32	31
Die.....	30	27	30	Kru.....	21	19	22
Die.....	32	31	30	Lee.....	28	30	28
Dun.....	31	33	31	Llo.....	23	24	24
Edw.....	25	26	26	May.....	20	20	19
Eic.....	26	26	24	Mui.....	28	27	28
Eve.....	23	23	25	Neu.....	27	28	27
Far.....	28	28	30	Oyl.....	24	25	26
Fie.....	31	29	32	Pow.....	33	34	35
Fin.....	28	28	28	Rad.....	26	24	27
Fle.....	26	26	28	Rob.....	29	28	29
Flo.....	20	20	20	Ros.....	28	30	29
Fre.....	17	18	17	Sew.....	35	35	36
Gat.....	21	21	19	Sne.....	29	28	30
Gri-1.....	23	24	21	Tho-1.....	29	29	31
Gri-2.....	21	21	21	Tho-2.....	27	29	29
Ham.....	24	25	23	Tow.....	30	31	30
Har.....	27	28	27	Was-1.....	33	34	33
Hig.....	29	28	29	Was-2.....	23	22	22
Him.....	25	26	26	Wea.....	24	25	23
Hin.....	25	25	26	Web.....	22	23	21
Hip.....	24	25	27	Whi.....	22	23	23
Hug.....	27	28	28	Wie.....	32	29	33
Hyd.....	17	17	19	Wil.....	25	27	26
Jen-1.....	32	32	33	Wis.....	28	28	29
Jen-2.....	19	19	21				
Kel.....	25	24	26				
Klo.....	26	27	28				

TABLE IVa.—(Continued)

Goiter				Non-goiter			
Subject	Average 20 trials	Average 1 & 2	Average 19 & 20	Subject	Average 20 trials	Average 1 & 2	Average 19 & 20
Lag.....	35	38	34				
Lan.....	21	22	23				
Lay.....	24	25	25				
Lee.....	24	24	25				
Lew.....	24	26	24				
Lip.....	28	29	27				
Llo.....	23	23	24				
Luc.....	31	30	32				
Mar.....	28	28	27				
Mas.....	24	24	25				
Mcg.....	22	22	23				
Mig-1.....	24	25	23				
Mig-2.....	22	22	22				
Mil-1.....	33	33	34				
Mil-2.....	28	29	27				
Mil-3.....	26	28	27				
Mos.....	22	23	22				
Nol.....	29	30	29				
Ode.....	27	27	27				
Odg.....	27	28	27				
Olm.....	29	32	29				
Pha.....	24	26	24				
Ple.....	24	26	25				
Plu.....	23	27	27				
Poo.....	29	30	29				
Pre.....	32	32	31				
Pri.....	26	24	25				
Rei.....	29	26	30				
Ric.....	31	31	30				
Rob.....	29	29	30				
Rod.....	25	25	26				
Rut.....	30	28	30				
Sal-1.....	26	27	27				
Sal-2.....	23	22	23				
Sca.....	17	19	19				
Sch-1.....	32	29	32				
Sch-2.....	20	20	20				
Sho.....	27	28	27				
Sip.....	22	21	20				
Sto.....	23	26	23				
Str.....	29	29	29				
Ten.....	26	27	27				
Twl.....	27	27	28				
Wag.....	20	23	19				
Wal.....	25	27	23				
War.....	26	26	27				
Wat.....	30	30	30				
Web.....	23	22	22				
Wri.....	19	21	19				

Average 20 trails	Average 20 trials
Number tested..... 103	Number tested..... 51
Total score..... 2641.31	Total score..... 1372.10
Mean..... $25.64 \pm .2555$	Mean..... $26.9 \pm .3260$
M.D..... 3.12	M.D..... 2.79
S.D..... $3.8418 \pm .1805$	S.D..... $3.4519 \pm .2307$
Range..... 17-35	Range..... 20-35

Difference in mean.....	$1.26 \pm .4141$
D.....	
P.E.D.....	3.04
Difference in S.D.....	$3899 \pm .2929$
D.....	
P.E.D.....	1.3311

Average 1 & 2	Average 1 & 2
Number tested..... 103	Number tested..... 51
Total score..... 2675.3	Total score..... 1376
Mean..... $25.9 \pm .2435$	Mean..... $26.9 \pm .3224$
M.D..... 2.9	M.D..... 2.6
S.D..... $3.6672 \pm .1723$	S.D..... $3.4130 \pm .2279$
Range..... 17-38	Range..... 19-35

Difference in mean.....	$1.0 \pm .4040$
D.....	
P.E.D.....	2.48
Difference in S.D.....	$.2542 \pm .2857$
D.....	
P.E.D.....	.89

Average 19 & 20	Average 19 & 20
Number tested..... 103	Number tested..... 51
Total score..... 2671.9	Total score..... 1383.6
Mean..... $25.9 \pm .2614$	Mean..... $27.1 \pm .3501$
M.D..... 3.0	M.D..... 3.1
S.D..... $3.9360 \pm .1850$	S.D..... $3.7073 \pm .2476$
Range..... 17-34	Range..... 19-36

Difference in mean.....	$1.2 \pm .4369$
D.....	
P.E.D.....	2.75
Difference in S.D.....	$.2287 \pm .3091$
D.....	
P.E.D.....	.74

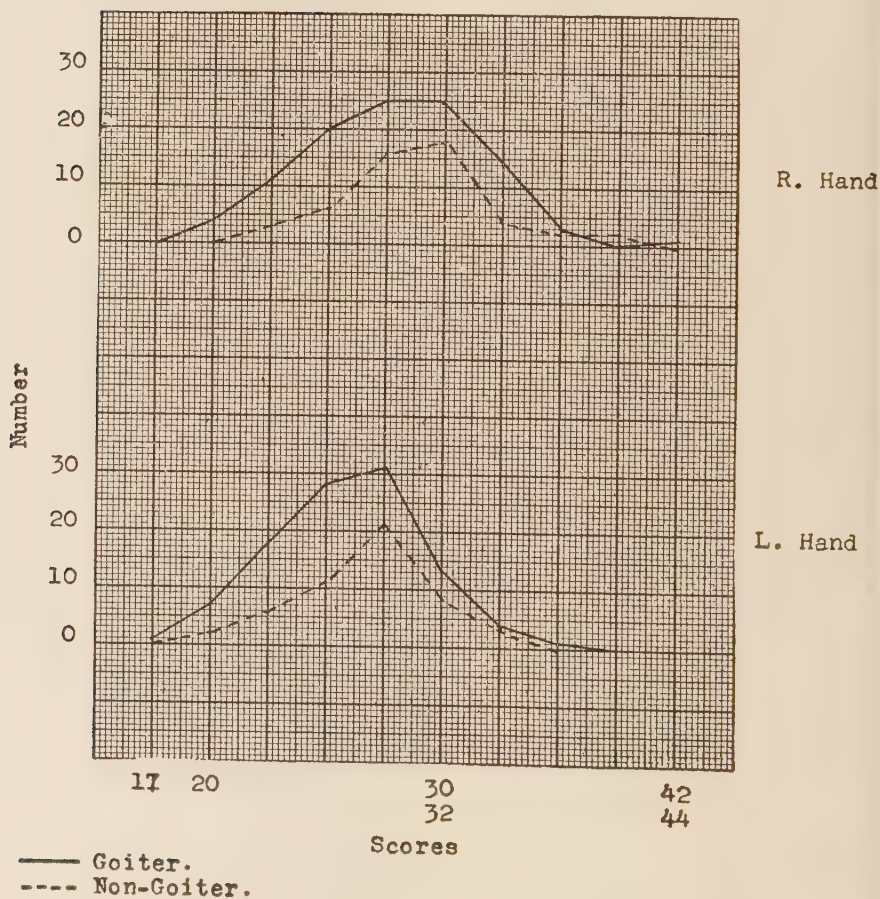


FIG. 11.—Distribution of scores. Dynamometer test. Ave. 1 and 2.

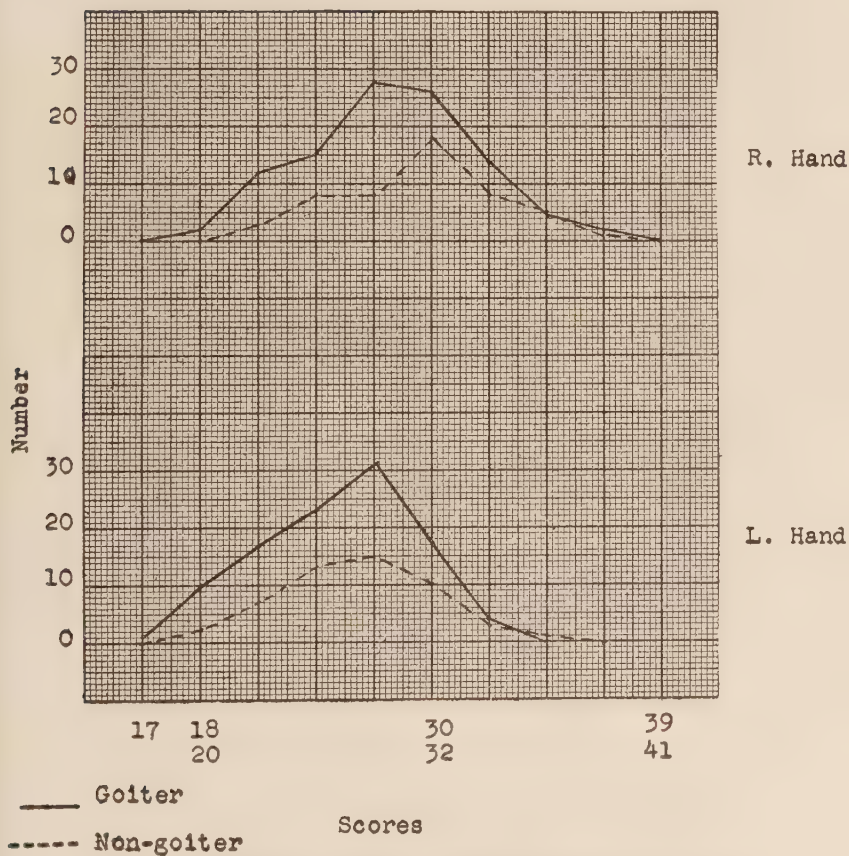


FIG. 12.—Distribution of scores. Dynamometer test. Ave. 19 and 20.

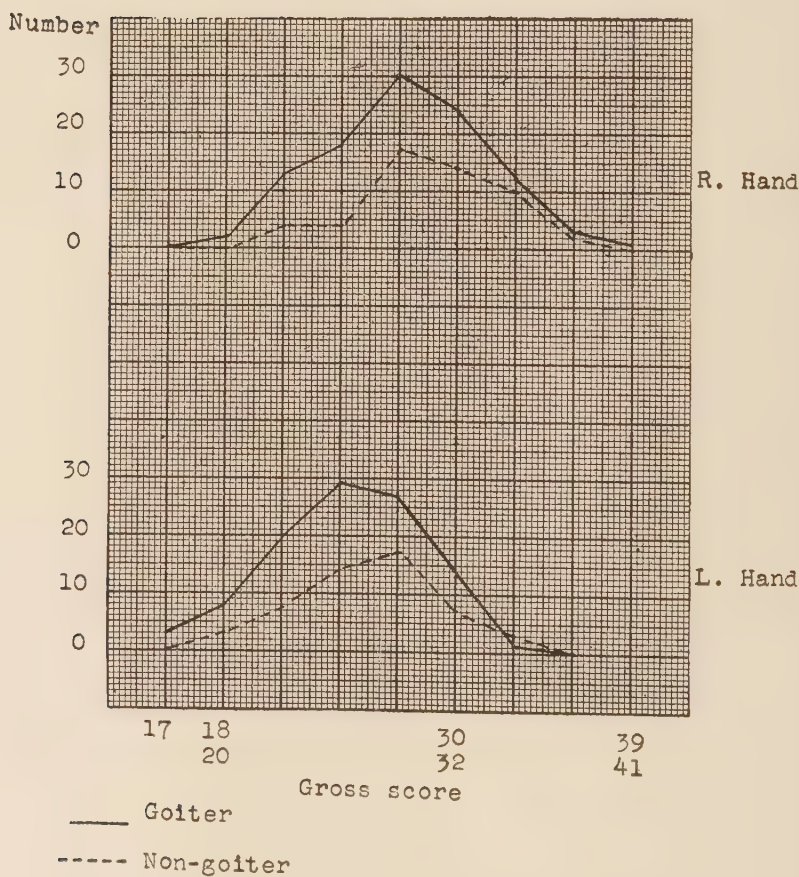


FIG. 13.—Distribution of gross scores. Dynamometer test.

group is no more variable than the other. And that there are no differences of statistical significance is indicated by the fact that none of the reliability quotients exceed 2.7.

Considering individuals, Jen-1 made a gross score of 38, and an average score of 38 for the first and second trials with an average score of 40 for the nineteenth and twentieth trials with the right hand, the same scores for the left hand being 32, 32, and 33. This subject is taller and heavier for her age than the other subjects, her weight being in muscle and bony structure rather than in flesh. Lag. with the right hand made a gross score of 40, an average for the first two trials of 42 and for the last two trials, an average of 40, which were the best right hand scores made. For the left hand her scores were 36, 38, and 34. The lowest scores were also made in the goiter group. These were made by Hyd., Fre., Ask., App., Wri., Sca., and Coc. It will be recalled that Fre., Ask. and Coc. did poorly in the steadiness and coördination tests, and are subjects who show thyrotoxic symptoms while Hyd. is a hypo-thyroid subject. In the non-goiter group there are no markedly low scores, and no scores over 39. The performance of the individuals in this group is comparatively constant which accounts for the slight superiority of the group performance.

Smedley's table of norms for girls from 12 to 18 years, abstracted from tables for girls from 6 to 18 years, based on the examination of 3471 Chicago girls, and Carman's tables based on the examination of 563 girls from 12 to 19 years are reproduced here in table IVb, for purposes of comparison with the results of the present study. Smedley used a Smedley dynamometer, Miss Carman a Collin dynamometer. Neither used a series of twenty trials for both right and left hands.

TABLE IVb.—AGE NORMS

Age	Right				Left			
	S,* kg.	C,* kg.	N*		S, kg.	C, kg.	N	
			G, kg.	N-G, kg.			G, kg.	N-G, kg.
12	19	15	22	28	18	14	22	25
13	22	18	24	..	20	16	24	
14	25	20	26	26	23	17	23	24
15	27	21	27	29	25	18	24	28
16	29	21	30	29	27	18	28	27
17	30	23	30	32	27	22	27	28
18	30	24	29	30	28	22	26	27
19	..	23	29	31	..	20	28	28
20	..	..	27	..	..	..	25	
21	..	..	..	32	..	..	..	27

* S—Smedley.

C—Carman.

N—Nelson.

Omitting the 12 and 21 year groups, because in this study they represent but one subject and not a group average, the records presented here agree or closely approximate the Smedley norms for the successive age groups for both hands, for both the goiter and non-goiter groups. For the same ages Miss Carman's figures are very much lower. The difference in the instruments used may, in a large part, account for this difference. A very clear verification is found in the records presented—that strength of grip increases with age. The studies of Smedley and Miss Carman are the only ones reported that are approximately similar to the present one, except that of Hastings, but as his Manual was not available his figures could not be reproduced.

That the dynamometer does not measure fatigue, in this experiment at least, will be shown by a glance at tables IV and IVa. With 84.4 per cent of the subjects the final efficiency score equals or surpasses the initial efficiency score in the right hand and for the left hand the same is true of 78.6 per cent of the cases for the goiter group. About the same percentages hold for the non-goiter group. In fact, in both groups the gross score, initial efficiency, and final efficiency scores very nearly correspond. Examples are:

	Av. of 20 trials, kg.	Av. of 1 and 2, kg.	Av. of 19 and 20, kg.
Dav-1.....	26	26	27
Fle.....	31	31	32
Sho.....	30	30	29
Bla-2.....	31	32	31
Cha.....	27	27	27
Ric.....	29	29	30

Subdividing the goiter group into its four sub-divisions and subjecting these groups to statistical analyses reveals no significant group differences, merely chance variations. That there are no differences of statistical significance is further indicated by the fact that in all comparisons, the reliability quotients are without exception less than 4. Tables IVc, d, e, and f give a summary for these groups. The accompanying figures, 14, 15, and 16, show the right and left hand distribution for the four groups.

COMPARISON OF THE GOITER AND NON-GOITER GROUPS IN THE TAPPING TEST

Since von Kries (1886) first measured the maximum rate of repeated voluntary movements, tapping as rapidly as possible for a period of from 5 seconds

TABLE IVc.—DYNAMOMETER TEST. THYROID SUB-GROUPS

Slight thyroid enlargement					Adenomata								
Subject	Right hand			Left hand			Subject	Right hand			Left hand		
	Av. 20 trial	Av. 1 & 2	Av. 19 & 20	Av. 20 trial	Av. 1 & 2	Av. 19 & 20		Av. 20 trial	Av. 1 & 2	Av. 19 & 20	Av. 20 trial	Av. 1 & 2	Av. 19 & 20
And.....	22	23	23	22	21	21	Atk.....	29	30	28	27	27	27
App.....	23	21	25	19	21	21	Bar.....	24	23	25	22	22	24
Aye.....	31	31	30	28	29	32	Coc.....	20	20	21	18	18	30
Ber.....	37	38	36	29	33	38	Die.....	33	34	36	32	31	30
Bla-1.....	33	31	35	27	27	28	Dun.....	31	31	29	31	33	31
Bla-2.....	31	32	31	29	29	30	Hin.....	27	27	26	25	25	26
Boo.....	24	25	25	23	27	23	Hip.....	26	26	28	24	25	27
Bro.....	31	29	31	29	27	29	Lag.....	40	42	40	35	38	34
Cha-2.....	23	24	23	23	23	23	Lee.....	27	27	28	24	24	25
Clo.....	33	32	31	25	28	24	Mas.....	26	27	28	24	24	25
Coo.....	28	25	29	25	25	26	Mig-1.....	24	23	22	24	25	23
Cro-1.....	36	34	38	30	33	33	Mig-2.....	23	24	23	22	22	22
Cro-2.....	32	31	34	29	30	28	Nol.....	35	35	36	29	30	29
Cun.....	32	36	32	28	30	34	Olm.....	33	34	35	29	32	29
Dav-2.....	31	29	32	26	25	26	Ple.....	26	26	27	24	26	25
Edw.....	28	29	30	25	26	26	Pri.....	29	27	29	26	24	25
Eic.....	29	29	30	26	26	24	Rei.....	28	25	28	29	26	30
Fie.....	31	30	32	31	32	32	Str.....	35	35	35	29	29	29
Fre.....	23	20	20	17	18	17	Web.....	24	24	25	23	22	22
Gri-2.....	23	22	23	21	21	21							
Ham.....	28	28	28	24	25	23							
Har.....	30	31	33	27	28	27							
Hug.....	29	28	30	27	28	28							
Hyd.....	21	19	22	17	17	19							

	38	38	40	32	32	33
Jen-1.....	38	38	40	32	32	33
Klo.....	33	33	35	26	27	28
Lew.....	27	27	26	24	26	24
Mar.....	32	32	28	33	28	27
Mil-1.....	35	33	35	33	33	34
Plu.....	24	30	29	23	27	27
Pre.....	33	33	33	32	32	31
Rac.....	29	29	30	31	31	30
Sa-l.....	29	30	26	27	27	27
Sca.....	19	18	18	17	19	19
Sip.....	22	22	21	23	21	20
Wag.....	25	25	20	20	23	19
Wal.....	29	31	29	25	27	23
War.....	31	33	32	26	26	27
Wat.....	29	30	30	30	30	30
Wri.....	26	27	26	19	21	19

Average 20 trials		Average 20 trials		Average 20 trials		Average 20 trials	
Number tested.....	40	Number tested.....	40	Number tested.....	19	Number tested.....	19
Total score.....	1148.44	Total score.....	1020.53	Total score.....	542.08	Total score.....	488.43
Mean.....	28.71 ± .4887	Mean.....	25.51 ± .4605	Mean.....	28.53 ± .7495	Mean.....	25.70 ± .5077
M.D.....	3.67	M.D.....	3.49	M.D.....	3.93	M.D.....	2.68
S.D.....	4.5821 ± .3456	S.D.....	4.3182 ± .3256	S.D.....	4.8438 ± .5300	S.D.....	3.2812 ± .3590
Range.....	19-38	Range.....	17-33	Range.....	20-40	Range.....	18-35

Average 1 & 2		Average 1 & 2		Average 1 & 2		Average 1 & 2	
Number tested.....	40	Number tested.....	40	Number tested.....	19	Number tested.....	19
Total score.....	1147.10	Total score.....	1054.50	Total score.....	530.20	Total score.....	500.6
Mean.....	28.7 ± .4990	Mean.....	26.4 ± .4432	Mean.....	27.93 ± .8044	Mean.....	26.3 ± .5740
M.D.....	3.7	M.D.....	3.26	M.D.....	4.0	M.D.....	3.0
S.D.....	4.6789 ± .3528	S.D.....	4.1559 ± .3134	S.D.....	5.1984 ± .5688	S.D.....	3.7095 ± .4059
Range.....	19-38	Range.....	17-34	Range.....	20-42	Range.....	18-38

Average 19 & 20		Average 19 & 20		Average 19 & 20		Average 19 & 20	
Number tested.....	40	Number tested.....	40	Number tested.....	19	Number tested.....	19
Total score.....	1174.50	Total score.....	1034.90	Total score.....	547.2	Total score.....	501.6
Mean.....	29.4 ± .5143	Mean.....	25.9 ± .4669	Mean.....	28.8 ± .7782	Mean.....	26.4 ± .5762
M.D.....	3.76	M.D.....	3.67	M.D.....	3.9	M.D.....	3.0
S.D.....	4.8226 ± .3637	S.D.....	4.3784 ± .3301	S.D.....	5.0294 ± .5503	S.D.....	3.7236 ± .4074
Range.....	18-40	Range.....	17-34	Range.....	21-40	Range.....	18-34

Average 20 trials				Average 20 trials				Average 20 trials				Average 20 trials			
Number tested.....	15			Number tested.....	15			Number tested.....	29			Number tested.....	29		
Total score.....	436.3			Total score.....	393.01			Total score.....	796.62			Total score.....	721.14		
Mean.....	29.07 ± .5710			Mean.....	26.20 ± .5864			Mean.....	27.46 ± .4053			Mean.....	24.86 ± .4174		
M.D.....	2.46			M.D.....	2.83			M.D.....	2.80			M.D.....	2.82		
S.D.....	3.2789 ± .4038			S.D.....	3.3673 ± .4146			S.D.....	3.2361 ± .2866			S.D.....	3.3325 ± .2951		
Range.....	22-34			Range.....	20-31			Range.....	22-33			Range.....	19-35		
Average 1 & 2				Average 1 & 2				Average 1 & 2				Average 1 & 2			
Number tested.....	15			Number tested.....	15			Number tested.....	29			Number tested.....	29		
Total score.....	436.6			Total score.....	395.1			Total score.....	785.20			Total score.....	724.30		
Mean.....	29.1 ± .5339			Mean.....	26.3 ± .5660			Mean.....	27.0 ± .4349			Mean.....	24.9 ± .3681		
M.D.....	2.4			M.D.....	2.6			M.D.....	3.0			M.D.....	2.5		
S.D.....	3.0656 ± .3775			S.D.....	3.2500 ± .4002			S.D.....	3.4720 ± .3075			S.D.....	2.9387 ± .2603		
Range.....	23-35			Range.....	20-32			Range.....	21-33			Range.....	19-38		
Mil-2.....	28	28	27	Mil-2.....	28	28	27	Mil-2.....	28	28	27	Mil-2.....	28	28	27
Mos.....	24	24	23	Mos.....	31	30	32	Mos.....	31	30	32	Mos.....	22	23	22
Ode.....	31	31	30	Ode.....	31	32	33	Ode.....	31	32	33	Ode.....	27	27	27
Odg.....	31	31	30	Odg.....	31	32	33	Odg.....	31	32	33	Odg.....	27	28	27
Rob.....	30	30	31	Rob.....	30	30	31	Rob.....	30	30	31	Rob.....	29	29	30
Rod.....	28	28	29	Rod.....	28	28	29	Rod.....	28	28	29	Rod.....	25	25	26
Rut.....	31	31	31	Rut.....	31	28	31	Rut.....	31	28	31	Rut.....	30	28	30
Sal-2.....	25	25	26	Sal-2.....	25	26	26	Sal-2.....	25	26	26	Sal-2.....	23	22	23
Sch-1.....	33	33	31	Sch-1.....	33	31	35	Sch-1.....	33	31	35	Sch-1.....	32	29	32
Sch-2.....	25	25	22	Sch-2.....	25	22	25	Sch-2.....	25	22	25	Sch-2.....	20	20	20
Ten.....	32	32	34	Ten.....	32	33	34	Ten.....	32	33	34	Ten.....	26	27	27
Twi.....	26	26	27	Twi.....	26	26	27	Twi.....	26	26	27	Twi.....	27	27	28

to 2 minutes with a pencil, stylus, or telegraph key or making dots on paper, have served as a test of voluntary motor ability and fatigue. Wells and Whipple have standardized this test which has been put to an almost endless variety of uses.

TABLE IVc.—DIFFERENCES FOR CONSTANTS FOR GOITER SUB-GROUPS IN DYNAMOMETER TEST

Groups compared	Right hand, average gross score			
	Diff. in M.	D. P.E.D.	Diff. in S.D.	D. P.E.D.
Large-medium.....	1.61 ± .7002	2.30	0.0428 ± .4952	0.09
Large-slight.....	0.36 ± .7516	0.48	1.3032 ± .5315	2.45
Large-adenoma.....	0.52 ± .9422	0.55	1.6649 ± .6663	2.50
Medium-slight.....	1.25 ± .6350	1.97	1.3460 ± .4490	3.00
Medium-adenoma.....	1.07 ± .8521	1.26	1.6077 ± .6025	2.67
Slight-adenoma.....	0.18 ± .8948	0.20	0.2617 ± .6327	0.41

Average 1 and 2

Large-medium.....	2.1 ± .6886	3.05	0.4064 ± .4869	0.84
Large-slight.....	0.4 ± .7308	0.55	1.6133 ± .5168	3.12
Large-adenoma.....	1.2 ± .9655	1.24	2.1328 ± .6827	3.12
Medium-slight.....	1.7 ± .6619	2.57	1.2069 ± .4680	2.58
Medium-adenoma.....	0.9 ± .9144	0.98	1.7264 ± .6466	2.67
Slight-adenoma.....	0.8 ± .9466	0.85	0.5195 ± .6701	0.78

Average 19 and 20

Large-medium.....	1.4 ± .7609	1.83	0.2260 ± .5390	0.42
Large-slight.....	0.1 ± .7934	0.13	1.3536 ± .5611	2.41
Large-adenoma.....	0.5 ± .9852	0.51	1.5604 ± .6967	2.25
Medium-slight.....	1.5 ± .6919	2.17	1.1276 ± .4902	2.30
Medium-adenoma.....	0.9 ± .9054	0.99	1.3344 ± .6402	2.10
Slight-adenoma.....	0.6 ± .8328	0.64	0.2068 ± .6596	0.31

TABLE IVf.—DIFFERENCES IN CONSTANTS FOR GOITER SUB-GROUPS
IN DYNAMOMETER TEST

Groups compared	Left hand, gross score			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	1.34 ± .7198	1.86	0.0348 ± .5089	0.07
Large-slight.....	0.69 ± .7456	0.93	0.9509 ± .5272	1.80
Large-adenoma.....	0.50 ± .7756	0.64	0.0861 ± .5484	0.16
Medium-slight.....	0.65 ± .6215	1.05	0.9857 ± .4394	2.24
Medium-adenoma.....	0.84 ± .6573	1.28	0.0513 ± .4147	0.11
Slight-adenoma.....	0.19 ± .6854	0.28	1.0370 ± .4847	2.14

Average 1 and 2

Large-medium.....	1.4 ± .6752	2.07	0.3113 ± .4774	0.65
Large-slight.....	0.1 ± .7189	0.14	0.9059 ± .5083	1.78
Large-adenoma.....	0.0 ± .8061	0.00	0.4595 ± .5700	0.81
Medium-slight.....	1.5 ± .5761	2.60	1.2172 ± .4074	2.89
Medium-adenoma.....	1.4 ± .6819	2.05	0.7708 ± .4822	1.60
Slight-adenoma.....	0.1 ± .7252	0.14	0.4464 ± .5128	0.87

Average 19 and 20

Large-medium.....	0.7 ±	<1	0.1099 ±	<1
Large-slight.....	0.3 ±	<1	0.8779 ± .5430	1.62
Large-adenoma.....	0.2 ±	<1	0.2231 ±	<1
Medium-slight.....	0.4 ±	<1	0.9878 ± .4463	2.21
Medium-adenoma.....	0.9 ± .7158	1.26	0.3330 ±	<1
Slight-adenoma.....	0.5 ±	<1	0.6548 ± .5243	1.25

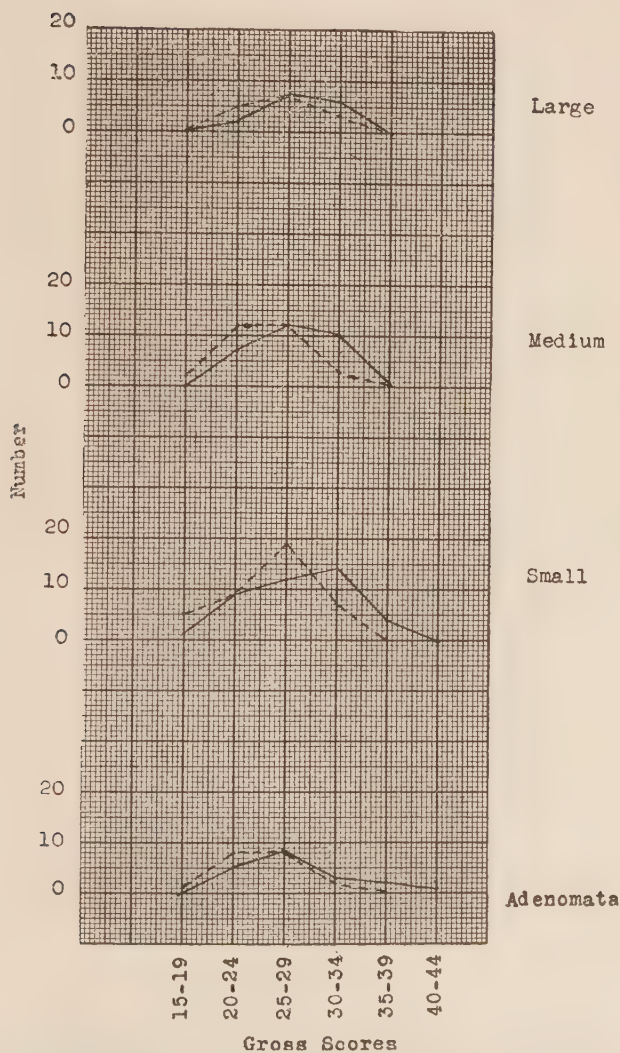


FIG. 14.—Goiter sub-groups. Dynamometer test. Distribution of gross scores. ———R. Hand -----L. Hand.

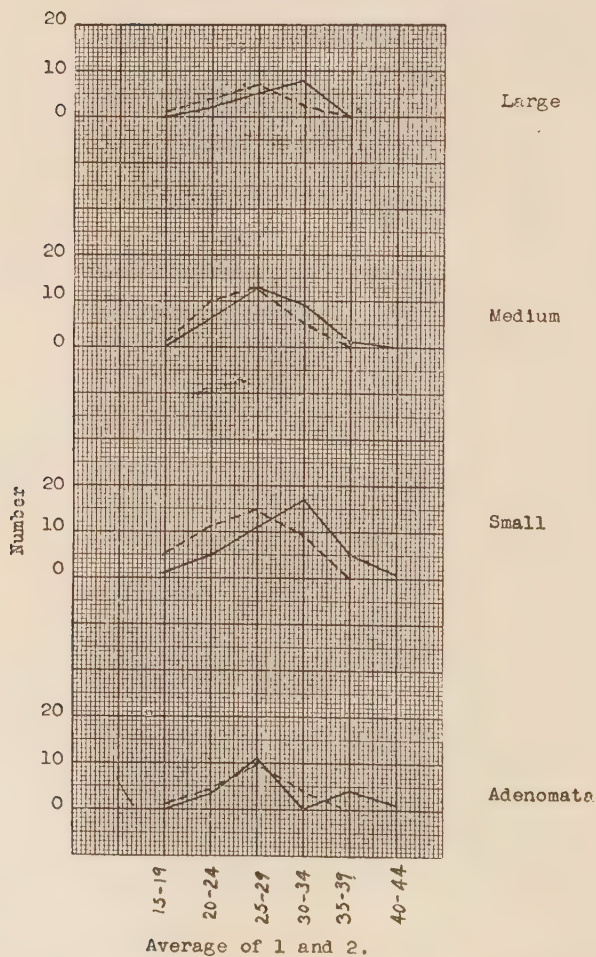


FIG. 15.—Goiter sub-groups. Dynamometer test. Distribution of averages of trials 1 and 2. ——— R. Hand. ---- L. Hand.

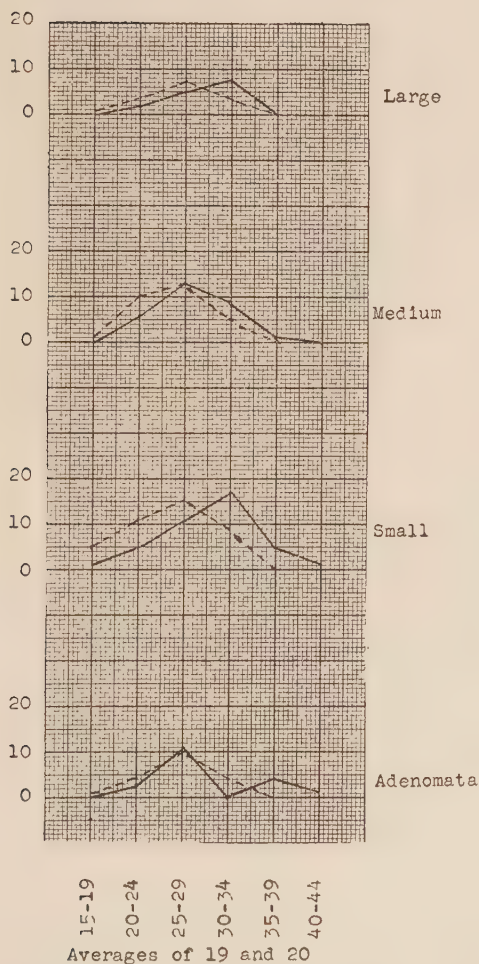


FIG. 16.—Goiter sub-groups. Dynamometer test. Distribution of averages of trials 19 and 20. ———R. Hand. - - - - -L. Hand.

What the physiological and psychological factors are that condition the maximum rate have not been determined. The physiological significance of the maximum rate, Wells considers, is limited by the refractory phase of the synapses in the motor pathways. Bolton, in discussing motor development explains that the maximum rate is based upon growth of interrelation between nerve elements; J. von Kries and Kirkpatrick support the view that the limit of the maximum rate is conditioned by neural elements. Whipple adds to the neural condition the condition of ability to coördinate voluntary movements. And, that Dunlap considers this condition important may be inferred from the tapping board which he devised and described in 1921 and which requires alternate tapping on two separate plates. Ream holds that the maximum rate is conditioned by an inherent physiological openness of nerve paths. Dodge and Benedict consider "the maximum rate to be conditioned not merely by the mass of the moving member, the strength of the muscles and the adequacy of motor coördination between antagonists, but also by the highly complex mental fact which we call 'will.'" That integrated attention is a contributory factor to speed is generally recognized.

The results of the tapping test of this experiment are presented in Tables V and Va and accompanying curves. Each of the five three place numbers, reading from left to right, gives the individual daily average of five sixty second trials for the five days of practice. The column headed "total" gives the total efficiency score.

The mean number of taps for the right and left hands of the goiter group is 297.2 and 254.9 respectively. The means for the non-goiter group for the right and left hands are 300.8 and 257.3 respectively. Compared in terms of variability the two groups show practically the

TABLE V.—TAPPING TEST—RIGHT HAND

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
And.....	253	312	316	320	328	306	Alb.....	180	194	209	222	220	205
App.....	272	282	...	...	...	277	Bay.....	298	...	332	327	308	316
Ask.....	249	300	303	259	307	284	Bil.....	224	241	258	...	...	241
Atk.....	248	264	278	240	302	266	Bro-1.....	302	305	304	317	337*	313
Aye.....	282	315	...	322	324	311	Bro-2.....	296	317	339	342	...	324
Bar.....	253	257	284	271	281	269	Bul.....	275	294	293	328	329	304
Ber.....	277	290	310	316	320	303	Car.....	288	317	348	362	371	337
Bla-1....	267	289	296	320	...	293	Che.....	263	289	310	326	328	303
Bla-2....	242	275	278	293	...	272	Cla.....	325	...	362	378	368	348
Boc.....	223	233	260	291	...	252	Cle.....	270	294	302	293	...	290
Boo.....	242	281	307	307	289	285	Cog.....	266	303	329	339	...	309
Bow.....	272	275	292	307	...	286	Col.....	279	332	367	389	396	353
Bro.....	268	299	325	314	316	305	Cor.....	241	237	227	276	...	245
Cha-1....	301	321	340	345	...	327	Din.....	169	197	222	236	244	218
Cha-2....	275	284	302	313	317	298	Fie.....	341	342	359	366	394	360
Clo.....	...	225	258	288	305	269	Fis.....	232	260	275	287	286	268
Coc.....	230	272	288	300	...	273	Gre.....	252	300	318	320	316*	301
Con.....	210	257	283	305	317	274	Gri.....	234	257	280	287	289	269
Coo.....	296	306	285	245	308	288	Gro.....	347	385	398	376	...	376
Cro-1....	289	309	332	359	354	329	Hal.....	355	361	389	391	...	374
Cro-2....	337	334	328	324	350	334	Ham.....	293	323	333	348	355*	330
Cro-3....	278	290	307	321	338	307	Har.....	340	368	382	405	409*	381
Cun.....	212	257	290	332	343	287	Hil.....	283	303	317	324	327*	311
Dan-1....	247	225	270	289	...	258	Hof.....	249	272	305	313	322	292
Dan-2....	238	271	297	313	331	290	Ire-1....	216	235	247	265	261*	245
Day-1....	328	363	381	385	...	384	Ire-2....	281	305	328	314	316*	309
Day-2....	261	292	318	343	...	303	Kno.....	275	298	315	330	...	305
Dic.....	310	335	...	318	344	328	Kru.....	236	282	307	305	315	289
Die.....	292	333	326	323	320	319	Lee.....	253	277	294	305	333	292
Dun.....	254	274	289	296	313	281	Llo.....	294	332	355	...	...	327
Edw.....	272	310	325	303	310	304	May.....	233	259	254	...	...	249
Ele.....	232	269	262	283	312	272	Mui.....	315	336	333	355	331*	334
Eve.....	289	338	351	352	350	336	Neu.....	231	241	279	...	...	250
Far.....	283	310	336	325	...	314	Oyl.....	223	260	255	270	307*	260
Fie.....	227	275	301	318	326	289	Pow.....	312	330	353	368	364*	345
Fin.....	269	295	306	310	314	299	Rad.....	211	244	294	324	337*	282
Fle.....	279	286	300	272	...	284	Rob.....	295	281	283	...	...	286
Flo.....	208	271	281	313	327	280	Ros.....	285	325	344	338	354*	329
Fre.....	321	350	343	354	357	345	Sew.....	262	...	271	287	299	280

TABLE V.—(Continued)

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
Gat.....	280	306	316	314	...	304	Sne.....	276	298	320	305	319*	304
Gri-1.....	295	302	295	346	...	310	Tho-1.....	253	269	295	310	310*	287
Gri-2.....	245	275	296	319	...	284	Tho-2.....	304	330	...	...	...	317
Ham.....	258	272	278	312	326	289	Tow.....	257	294	288	294	307*	286
Har.....	244	297	313	324	344	304	Was-1.....	255	...	292	299	307	288
Hig.....	278	292	286	312	340	301	Was-2.....	269	306	312	305	316	302
Him.....	261	283	303	313	321	296	Wea.....	279	294	297	293	296*	292
Hin.....	236	249	271	...	...	252	Web.....	264	304	322	344	339	315
Hip.....	240	276	323	342	...	295	Whi.....	314	...	353	344	350	340
Hug.....	284	295	309	306	...	299	Wie.....	225	243	266	293	291*	264
Hyd.....	177	196	237	253	260	225	Wil.....	279	299	309	312	334	306
Jen-1.....	276	284	303	315	314	298	Wis.....	261	293	302	290	307	291
Jen-2.....	240	263	281	303	312	280							
Kel.....	306	310	341	356	...	328							
Klo.....	344	333	303	356	340	335							
Lag.....	210	275	308	312	313	284							
Lan.....	282	294	324	336	...	309							
Lay.....	274	292	323	322	302	303							
Lee.....	248	275	274	290	301	278							
Lew.....	263	286	297	307	311	293							
Lip.....	258	302	323	320	337	308							
Llo.....	251	297	318	336	377	316							
Luc.....	268	289	292	300	...	287							
Mar.....	261	291	321	328	337	307							
Mas.....	230	269	282	290	303	275							
Mcg.....	264	308	303	323	330	306							
Mig-1.....	300	316	325	347	345	327							
Mig-2.....	298	304	336	349	353	328							
Mil-1.....	241	259	275	291	...	267							
Mil-2.....	265	274	285	325	341	298							
Mil-3.....	280	304	310	318	323	307							
Mos.....	286	328	335	342	339	326							
Nol.....	302	337	317	330	341	326							
Ode.....	263	280	295	304	304	289							
Odg.....	251	286	297	298	304	287							
Olm.....	311	333	342	346	326	332							
Pha.....	274	317	320	320	...	308							
Ple.....	233	268	282	299	...	271							
Plu.....	252	257	259	280	294	268							

TABLE V.—(Continued)

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
Poo.....	257	317	367	390	375	341							
Pre.....	237	254	261	281	288	264							
Pri.....	274	301	301	316	319	302							
Rei.....	243	286	315	329	348	304							
Ric.....	285	308	319	329	...	310							
Rob.....	248	247	295	304	...	274							
Rod.....	294	338	358	363	371	345							
Rut.....	273	318	345	351	360	329							
Sal-1.....	284	301	315	315	312	306							
Sal-2.....	279	321	326	341	335	321							
Sca.....	...	287	300	290	284	290							
Sch-1.....	284	299	292	308	...	296							
Sch-2.....	274	320	318	324	...	309							
Sho.....	267	294	302	294	...	289							
Sip.....	221	234	252	265	270	249							
Sto.....	304	329	327	338	333	326							
Str.....	261	296	321	330	326	307							
Ten.....	216	243	259	272	288	256							
Twl.....	226	251	254	279	289	260							
Wag.....	294	284	297	300	...	294							
Wal.....	243	261	275	288	...	267							
War.....	304	317	315	327	333	319							
Wat.....	250	283	297	294	...	281							
Web.....	270	314	323	324	325	311							
Wri.....	260	295	299	304	...	290							
Number tested.....	103						Number tested.....	51					
Total score.....	30614.5						Total score.....	15341.38					
Mean.....	297.2 ± 1.4876						Mean.....	300.8 ± 3.6036					
M.D.....	19.5						M.D.....	29.4					
S.D.....	22.4013 ± 1.0527						S.D.....	38.1543 ± 2.5481					
Range.....	225-384						Range.....	205-381					
Difference in mean.....	3.6 ± 3.8985												
D.....	.92												
P.E.D.....	15.7530 ± 3.7570												
Difference in S.D.....	4.19												
D.....													
P.E.D.....													

* Not consecutive days.

TABLE Va.—TAPPING TEST—LEFT HAND

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
And.....	211	246	273	299	283	262	Alb.....	204	233	254	263	273	245
App.....	240	252	...	...	...	246	Bay.....	237	...	262	255	261*	254
Ask.....	215	258	273	305	302	271	Bil.....	242	284	308	...	...	278
Atk.....	216	237	245	232	281	243	Bro-1.....	249	263	266	270	281*	266
Aye.....	236	265	...	271	285	264	Bro-2.....	224	245	255	263	...	247
Bar.....	217	240	253	271	273	251	Bul.....	221	242	246	252	266	245
Ber.....	236	265	291	295	296	277	Car.....	240	264	292	314	315	285
Bla-1.....	229	333	254	263	...	270	Che.....	231	250	264	279	288	262
Bla-2.....	206	239	242	255	...	235	Cla.....	265	...	290	303	287	286
Boc.....	190	201	220	239	...	212	Cle.....	220	219	210	206	...	214
Boo.....	197	218	231	223	229	219	Cog.....	220	231	256	275	...	246
Bow.....	229	247	273	289	...	260	Col.....	257	287	296	311	337	298
Bro.....	223	238	253	257	268	248	Cor.....	221	208	207	230	...	218
Cha-1.....	246	261	275	265	...	262	Din.....	182	210	223	220	226	201
Cha-2.....	239	242	259	280	292	262	Fie.....	289	298	306	301	308	300
Clo.....	...	172	181	208	224	196	Fis.....	180	212	223	245	255	223
Coc.....	190	211	215	226	...	210	Gre.....	233	266	279	298	296*	275
Con.....	196	227	240	249	255	232	Gri.....	205	228	239	251	255	236
Coo.....	244	251	221	228	286	246	Gro.....	283	334	327	324	...	317
Cro-1.....	241	253	279	282	289	269	Hal.....	272	275	281	288	...	279
Cro-2.....	252	257	261	290	308	274	Ham.....	217	246	265	276	297*	260
Cro-3.....	229	239	258	282	285	259	Har.....	274	290	308	322	325*	304
Cun.....	188	211	237	245	274	231	Hil.....	239	252	263	270	275*	260
Dan-1.....	221	236	260	274	...	248	Hof.....	217	245	271	282	293	262
Dan-2.....	208	232	252	259	264	243	Ire-1.....	200	210	217	232	224*	217
Day-1.....	270	307	324	336	...	309	Ire-2.....	230	248	260	258	266*	252
Day-2.....	201	237	256	365	...	265	Kno.....	228	243	265	274	...	253
Dic.....	260	287	...	298	303	287	Kru.....	198	224	259	262	273	243
Die.....	248	282	285	265	260	268	Lee.....	211	232	253	260	278	247
Dun.....	303	328	341	352	364	338	Llo.....	268	309	330	...	...	302
Edw.....	245	283	285	274	253	268	May.....	174	212	219	...	...	202
Eic.....	206	229	215	235	247	226	Mui.....	241	262	279	310	280*	274
Eve.....	262	293	289	290	291	285	Neu.....	204	218	256	...	...	226
Far.....	247	275	299	315	...	284	Oyl.....	211	230	234	229	268*	234
Fie.....	257	286	312	325	318	300	Pow.....	240	258	288	302	309*	279
Fin.....	209	239	256	260	276	248	Rad.....	188	229	268	278	277*	248
Fle.....	227	243	282	266	...	255	Rob.....	201	226	221	...	...	216
Flo.....	204	226	224	244	251	230	Ros.....	246	280	301	294	310*	286
Fre.....	248	290	277	296	311	284	Sew.....	222	...	227	237	260	236

TABLE Va.—(Continued)

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
Gat.....	251	282	242	251	...	257	Sne.....	247	257	277	279	282*	268
Gri-1.....	265	289	310	314	...	295	Tho-1.....	223	231	254	259	269*	247
Gri-2.....	214	240	245	265	...	241	Tho-2.....	240	268	...	...	...	254
Ham.....	222	238	266	280	298	261	Tow.....	202	218	236	245	266*	233
Har.....	202	236	271	279	287	255	Was-1.....	221	...	237	247	257	241
Hig.....	245	257	263	278	300	273	Was-2.....	228	262	265	283	280	264
Him.....	198	225	245	248	257	235	Wea.....	211	224	232	235	260*	232
Hin.....	206	226	249	...	...	227	Web.....	222	248	265	278	287	260
Hip.....	226	258	272	286	...	258	Whi.....	251	...	288	298	306	286
Hug.....	231	250	250	273	...	251	Wie.....	193	211	230	254	259*	229
Hyd.....	154	179	192	200	202	185	Wil.....	224	253	251	259	280	253
Jen-1.....	222	233	243	259	254	243	Wis.....	224	249	273	269	281	259
Jen-2.....	190	218	233	251	270	232							
Kel.....	265	269	292	313	...	285							
Klo.....	275	281	257	301	277	278							
Lag.....	204	234	250	254	265	241							
Lan.....	259	260	261	287	...	267							
Lay.....	253	266	288	293	299	280							
Lee.....	217	238	256	260	270	248							
Lew.....	211	215	231	235	245	227							
Lip.....	216	243	271	271	285	257							
Llo.....	204	236	261	281	306	258							
Luc.....	208	230	236	242	...	229							
Mar.....	209	244	265	265	275	252							
Mas.....	205	236	238	254	261	239							
Mcg.....	227	255	277	286	290	267							
Mig-1.....	259	274	279	302	315	286							
Mig-2.....	254	267	299	310	320	290							
Mil-1.....	216	232	239	251	...	235							
Mil-2.....	286	305	322	346	358	323							
Mil-3.....	236	257	268	274	280	263							
Mos.....	257	281	290	286	293	281							
Nol.....	250	272	270	266	287	269							
Ode.....	211	229	238	258	259	239							
Odg.....	215	250	255	257	267	248							
Olm.....	241	282	289	292	306	282							
Pha.....	236	237	273	276	...	256							
Ple.....	209	241	248	257	...	239							
Plu.....	226	236	239	255	263	244							

TABLE Va.—(Continued)

Goiter							Non-goiter						
Average scores							Average scores						
Subject	Days						Subject	Days					
	1	2	3	4	5	Total		1	2	3	4	5	Total
Poo.....	215	258	302	319	309	281							
Pre.....	208	224	252	256	267	241							
Pri.....	228	241	242	268	270	250							
Rei.....	222	256	283	288	300	270							
Ric.....	216	251	261	282	...	253							
Rob.....	212	224	249	266	...	238							
Rod.....	236	263	289	298	308	279							
Rut.....	218	257	284	294	296	270							
Sal-1.....	240	259	273	278	275	265							
Sal-2.....	227	267	284	295	306	276							
Sca.....	...	229	251	265	254	250							
Sch-1.....	291	273	270	281	...	279							
Sch-2.....	244	272	286	291	...	273							
Sho.....	187	199	216	222	...	206							
Sip.....	200	203	218	220	226	213							
Sto.....	244	267	259	249	269	258							
Str.....	219	244	264	286	280	259							
Ten.....	198	219	239	246	264	233							
Twi.....	286	319	332	345	356	328							
Wag.....	261	271	285	283	...	275							
Wal.....	192	212	213	228	...	211							
War.....	246	251	263	286	289	267							
Wat.....	263	281	316	334	...	274							
Web.....	250	289	277	289	287	278							
Wri.....	231	259	262	278	...	258							
Number tested..... 103							Number tested..... 51						
Total score..... 26511.4							Total score..... 13001.5						
Mean..... 257.3 ± 1.6969							Mean..... 254.9 ± 2.5109						
M.D..... 21.3							M.D..... 19.71						
S.D..... 25.5530 ± 1.2009							S.D..... 26.5848 ± 1.7755						
Range..... 185-338							Range..... 201-317						
Difference in mean.....							2.4 ± 3.0305						
D.													
P.E.D.							.79						
Difference in S.D.....							1.0318 ± 2.1435						
D.													
P.E.D.							.48						

* Not consecutive days.

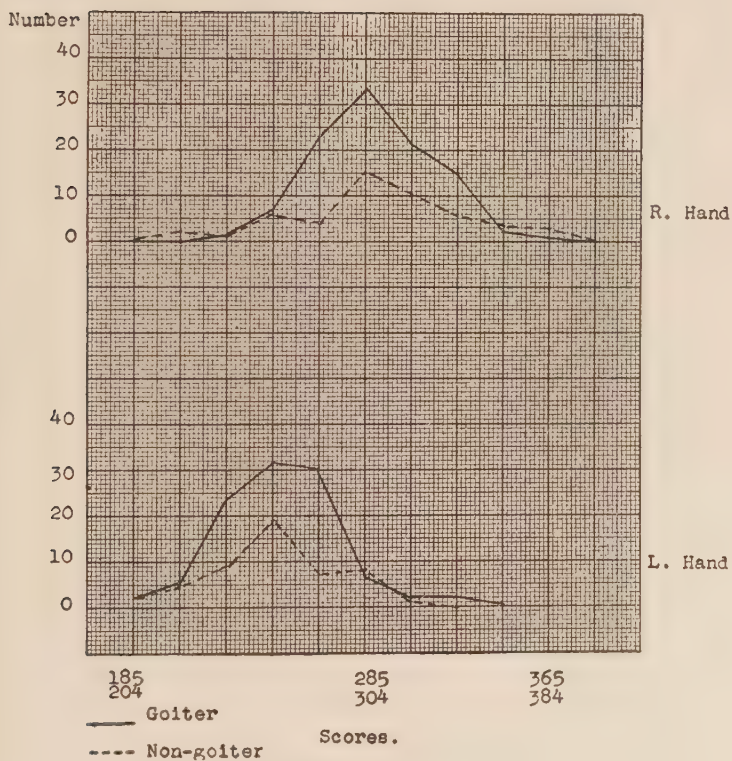


FIG. 17.—Distribution of scores. Tapping test.

same sigma for the left hand, this constant being 25.5 for the goiter group and 26.5 for the non-goiter group, for this hand. But that the non-goiter group is the more variable in the right hand is evidenced by the fact that for that hand the sigma is 38.1, while for the same hand in the goiter group it is only 22.4. Also the sigma reliability quotient, 4, for that hand indicates a difference not due to chance.

And as measured by the range of initial rate, which Wells considers an index of capacity, the non-goiter group is the more variable in the right hand where the range is from 169 to 355, while for the goiter group it is 177 to 344. This is further borne out by the fact that the mean initial rate of the former group is 270 and the sigma 39.40, while for the latter group these constants are 265 and 30.08 respectively.

When measured by range of initial rate alone, the reverse appears to be true for the left hand of the groups where the initial range for the goiter group is 154 to 303, and that for the non-goiter group 174 to 289. But the mean initial rates and the sigmas prove the left hand performance of the two groups to be on a uniform level, as the goiter group with a mean initial rate of 229 stands only two points above the non-goiter group and the sigmas for both groups are the same, 26.

The uniformity of performance of both groups in all tests suggests that the wider gamut of rates shown in tapping, in the right hand of the non-goiter group, may be interpreted as the result, not of differences in the native variabilities, age or constitutional differences, but of a handicap introduced into the goiter group as the result of exercise. It was noted that the hands of a considerable number of the goiterous subjects, particularly those showing tremor, perspired profusely causing the stylus to slip and the hands to blister and become

sore. It should be stated, however, that this handicap occurred in the right hand only, although both hands perspired. This may have been due to less pressure having been exerted with the left hand. The handicap introduced here was not noted to occur in the non-goiter group.

The figures discussed represent taps for one minute periods. For purposes of comparison with the figures of other workers each daily score was reduced to the average number of taps per second for the group. The average rate for the goiter group, for the right hand, is 4.84 taps per second, that for the non-goiter, 4.89 taps. The average rate for the left hand of the goiter group is 4.17 taps per second and for the non-goiter 4.13.

The maximum rate in the goiter group for the right and left hands is 6 and 5.6 taps respectively. The slowest rate in the same group is 3.6 taps per second for the right hand and 3 taps per second for the left hand. For the non-goiter group the maximum rate for the right hand is 6.2 taps per second, and the lowest is 3.3, while for the left hand the maximum rate is 5.2 and the minimum 3.3, and in this group more subjects reached or approximated the maximum rate than in the goiter group. The highest initial rate in this group is 6.5 taps per second and the lowest 2.9 for the right hand, with 4.8 for the highest initial rate and 1.9 for the lowest initial rate for the left hand. In the goiter group the initial rate ranges from 3 to 5.7 in the right hand and 2.8 to 5.1 in the left hand.

That duration of the tapping and method of procedure largely condition the average rate is generally accepted and these factors probably explain the comparatively low average rate for the groups of this study. The duration of tapping here was five sixty second periods,

with thirty second rest intervals. But the hands really rested two minutes since the right hand rested 30 seconds after tapping, plus 60 seconds while the left hand tapped, plus 30 seconds while the left hand rested. The method varied from that of the experimenters cited, in that the tapping board was not clamped to the top of the table and so tended to become displaced which made maintenance of body posture difficult. This caused the subject either to readjust the board, or adjust her position to its changed position; also there was a marked tendency, because of the amplitude of movement in tapping, to hit the wooden frame of the tapping board rather than the brass plate. In fact, this occurred so frequently that a slight groove was worn in the wood on either side of the board. Frequently too, the taps on the plate were too light to register, even though six and eight dry cells were used. And in the goiter group, as stated above, the hands of many subjects perspired very freely and blistered, and this, in turn, caused the stylus to slip, so that the subject was constantly readjusting it. In both groups great pressure and force were frequently exercised in tapping as was shown by the fact that in the course of the experiment, the stylus was twice gradually bent and finally broken, so that a steel point, which would not break, had to be substituted for the brass one.* All of these factors doubtless contributed to the comparatively low average scores cited. But since the conditions of the experiment were kept constant throughout for all subjects the rate is representative for these groups under the stated conditions.

The only similar studies reported for adolescent girls are those of Gilbert, Smedley and Dorcus. Other workers have reported average rates and maximum rates but the

* The two records, in which the stylus was broken during the course of the experiment, were discarded.

subjects used were either pre-adolescents or post-adolescents. Reducing Gilbert's and Smedley's figures to a group average for adolescents from 12 to 19 years and excluding the lower age groups, one gets a rate of 6.3 taps per second for the former worker and a rate of 6.0 taps per second for the latter. Dorcus reports, for college girls, a rate of 6.5 taps per second for the athletes and a rate of 6.2 for the non-athletes. His subjects, being college girls, were perhaps somewhat older than the girls of the other three studies. It will be noted that the rates given by these investigators are very much higher than the average rates obtained by the subjects of this study, but are practically the same as the maximum rates obtained in both groups of this study.

Smedley used an electrical counter to record taps for 30 seconds, and timed the work with an ordinary stop watch. Gilbert used a mechanical counter and allowed the subjects to tap 45 seconds, but counted taps for only the first five and the last five seconds, and gives figures in terms of taps in 5 seconds. Dorcus used the graphic method and allowed the subject to tap one sixty second period.

Consideration of the data from the viewpoint of individual variations within the groups is of particular interest. If, as Wells suggests, capacity for coördination and speed can be estimated from the initial rate, inspection of the individual initial scores shows that again among the low scores are those of several of the individuals with high pulse rate and tremor, as:

	Initial rate		Daily av. score		Pulse	Tremor
	R.	L.	R.	L.		
Coc.....	227	184	230	190	120	+
Ask.....	236	206	249	215	120	+
Con.....	198	185	210	196	112	—
Cun.....	225	182	212	188	104	+
Llo.....	256	185	251	204	118	+
Pre.....	232	203	237	208	120	+
Hyd.....	197	172	177	222	68	+
				(hypo)		

The trial to trial and day to day performances of these individuals are given in the following tabulations and subsequent curves. The tabulations reading from left to right are the five successive daily trials for the right and left hands with their mean variations. The figures reading from top to bottom, in each column, are the serial trials for five successive days.

The daily performance curves are plotted on the basis of the successive daily trial scores. The weekly performance—the unbroken curve—is plotted on the basis of the daily efficiency scores and represents the general level of performance or efficiency.

Coc.
Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	227	184	210	223	267	170	234	181	210	191	229.6	189.8	16.7	13.7
2	275	216	278	210	270	205	265	213	274	209	272.4	210.6	3.9	3.1
3	285	207	287	212	289	212	290	222	288	222	287.8	215.	1.4	5.6
4	304	224	305	230	302	221	305	225	286	288	300.4	225.6	5.7	2.7
5														
Av.....	273	208	270	219	282	202	274	210	265	213	272.5	210.2	6.9	6.2

Ask.
Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	236	206	239	213	259	207	266	225	246	225	249.2	215.2	10.6	7.8
2	306	263	308	268	308	243	319	258	261	258	300.4	258.	15.7	6.0
3	313	250	344	272	307	298	272	273	281	272	303.4	273.	21.5	10.0
4	312	294	242	298	202	312	286	317	252	304	258.8	305.	32.1	7.6
5	317	292	300	300	293	304	338	317	285	297	306.6	302.	16.7	6.8
Av.....	297	261	287	270	274	273	296	278	265	271	284.	271.	19.3	7.6

CUN.
Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	225	182	205	184	207	188	218	195	207	192	212.4	188.2	7.2	4.2
2	259	203	263	213	249	213	262	207	254	219	257.4	211.	4.7	4.8
3	283	238	312	242	285	232	281	225	288	248	289.8	237.	8.8	6.8
4	321	247	325	238	331	262	368	241	312	238	331.8	245.2	14.4	7.4
5	345	270	350	278	365	273	333	272	322	278	343.	274.2	12.4	3.0
Av.....	287	228	291	231	287	234	292	228	277	235	287.	231.	9.5	5.2

CON.
Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	198	185	204	186	207	194	202	195	238	218	209.8	195.6	11.2	8.9
2	260	222	253	218	260	229	259	224	251	242	256.6	227.	3.6	6.8
3	276	230	279	248	275	240	284	238	299	242	282.6	239.6	7.1	4.4
4	307	245	309	247	305	250	303	250	300	255	304.8	249.4	2.6	2.7
5	308	248	312	254	325	260	324	259	315	254	316.8	255.	6.1	3.6
Av.....	270	228	271	231	274	235	274	255	281	243	274.	232.	6.1	5.2

LLO.

Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	256	185	250	198	240	205	258	221	252	209	251.2	203.6	4.9	9.6
2	296	222	298	242	300	249	308	244	282	225	296.8	236.2	6.2	10.1
3	316	249	321	252	317	271	319	264	319	268	318.4	260.8	1.5	8.2
4	340	272	332	285	348	289	323	287	335	273	335.6	281.2	6.7	6.9
5	373	292	380	310	376	307	384	297	370	322	376.6	305.6	4.3	8.8
Av.....	316	244	316	257	316	264	318	263	311	259	315.8	257.6	4.7	8.7

PRE.

Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	232	203	249	207	244	205	223	209	236	218	236.8	208.4	7.7	4.0
2	244	220	251	222	248	213	268	235	258	229	253.8	223.8	7.3	6.5
3	260	249	268	255	276	254	236	250	264	251	260.8	251.8	10.2	2.1
4	290	263	293	264	286	266	270	241	265	246	280.8	256.	10.6	10.0
5	294	258	292	276	304	269	291	270	260	261	288.2	266.8	11.2	5.8
Av.....	264	239	271	245	272	241	258	241	257	241	264.	241.3	9.4	5.6

HYD.

Trials

Das.	1		2		3		4		5		Av.		M.V.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	197	172	140	143	180	145	186	160	183	151	177.2	154.2	14.8	9.4
2	185	171	200	182	198	184	180	177	219	180	196.4	178.8	11.1	3.8
3	245	201	235	195	236	189	229	191	239	182	236.8	191.6	4.1	5.1
4	258	206	256	190	245	198	259	200	248	207	253.2	200.2	5.3	5.0
5	255	206	255	179	262	188	264	219	263	220	259.8	202.4	3.8	15.1
Av.....	228	191	217	178	224	181	224	189	230	188	224.6	185.4	7.8	7.6

The tabulations reading from left to right show marked variability in the number of taps made in the five successive sixty second trials and a general tendency to a progressive loss of efficiency. The rate for the last trial in the right hand tends to be less than that of initial trial. In the left hand the reverse tends to be true, though not consistently so for all subjects. It will be recalled that the precedence of the right hand remained constant each of the five days. It may be that work done with the right hand has effected a general warming up, contributing to the efficiency of the left hand. But the mean variations do not consistently and regularly become smaller with practice in either hand. They show marked variability. Yet practice is supposed to bring down the mean variation and to decrease individual differences. The failure for this to occur in these seven records may be interpreted to mean that these individuals have not reached the practice limit, but are still in the early stages and that in consequence fatigue cannot be expected to have set in or the physiological limit to have been reached.

However the marked variability and the tendency to progressive loss of efficiency shown in the daily work curves suggest a susceptibility to fatigue on the part of these subjects. Another factor suggesting fatigability was an exaggerated tremor of the hands each day at the close of the tapping experiment. And, too, these individuals and two others—Har. and Pha.—stated that this test made them tremble. No subject in the non-goiter group made this complaint.

Because of these suggestive factors, fatigue indices were computed for all individuals in both groups. It is realized, of course, that to obtain a true index of fatigue, to make an intensive study of its course, and to obtain a measure of very fine fluctuations, a kymographic record,

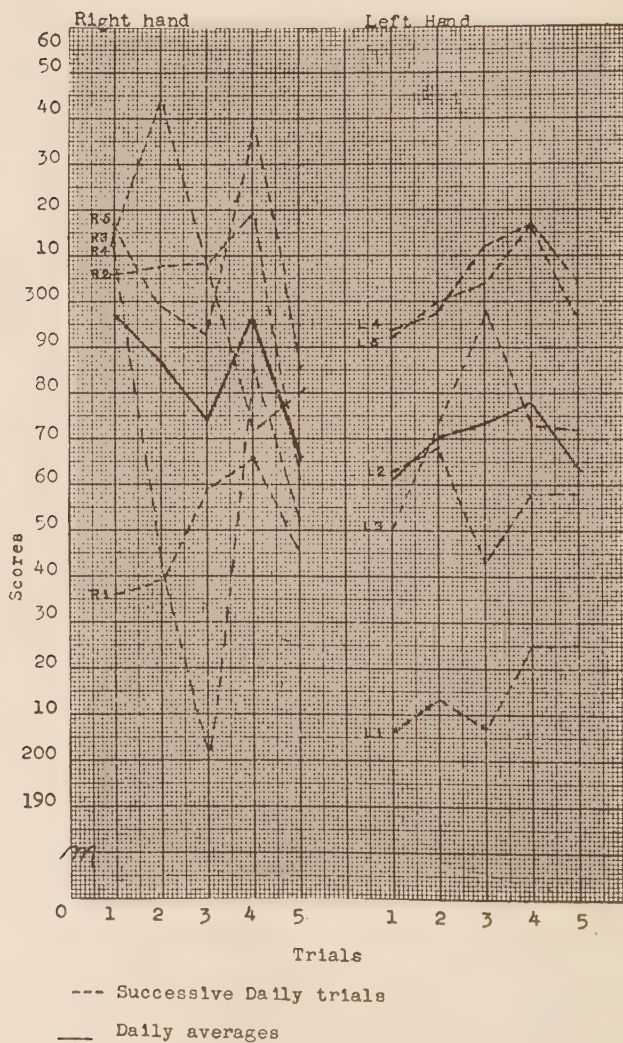


Fig. 18.—Sub., Ask. Daily performance and general efficiency level.

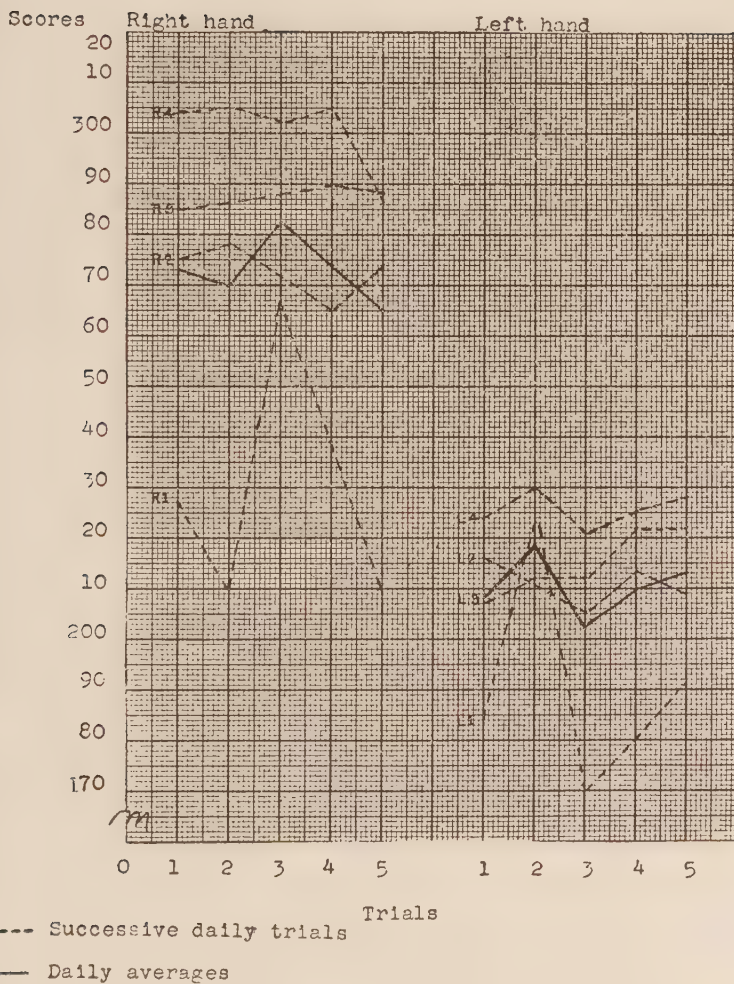


FIG. 19.—Sub., Coc. Daily performance and general efficiency level.

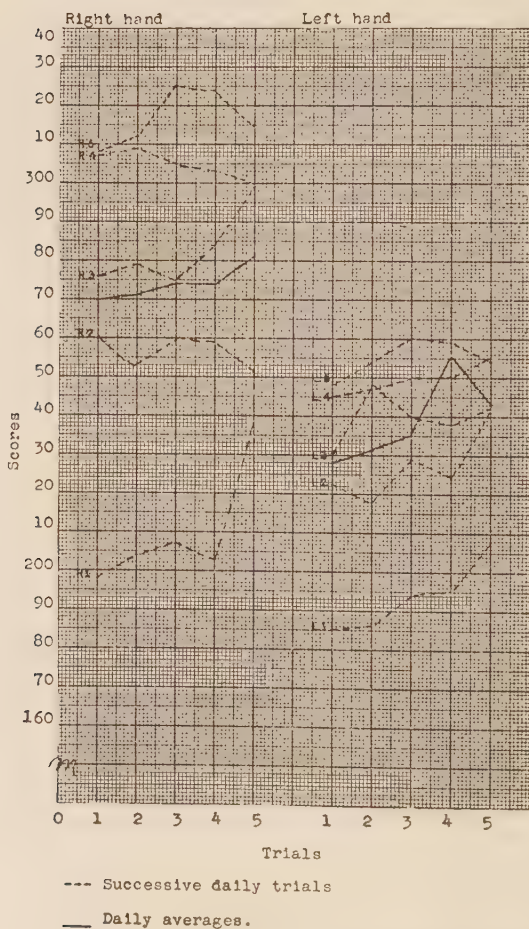


FIG. 20.—Subj. Con. Daily performance and general efficiency level.

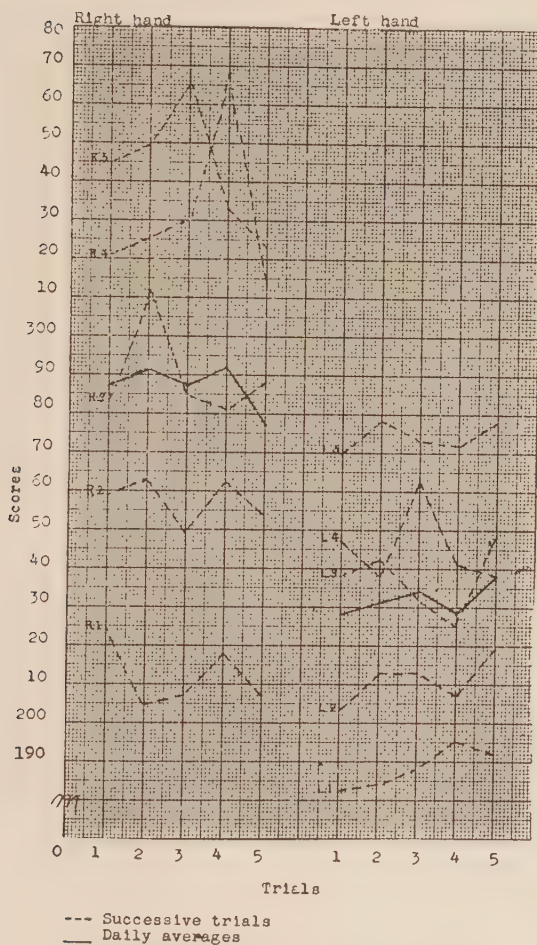


FIG. 21.—Subj. Cun. Daily performance and general efficiency level.

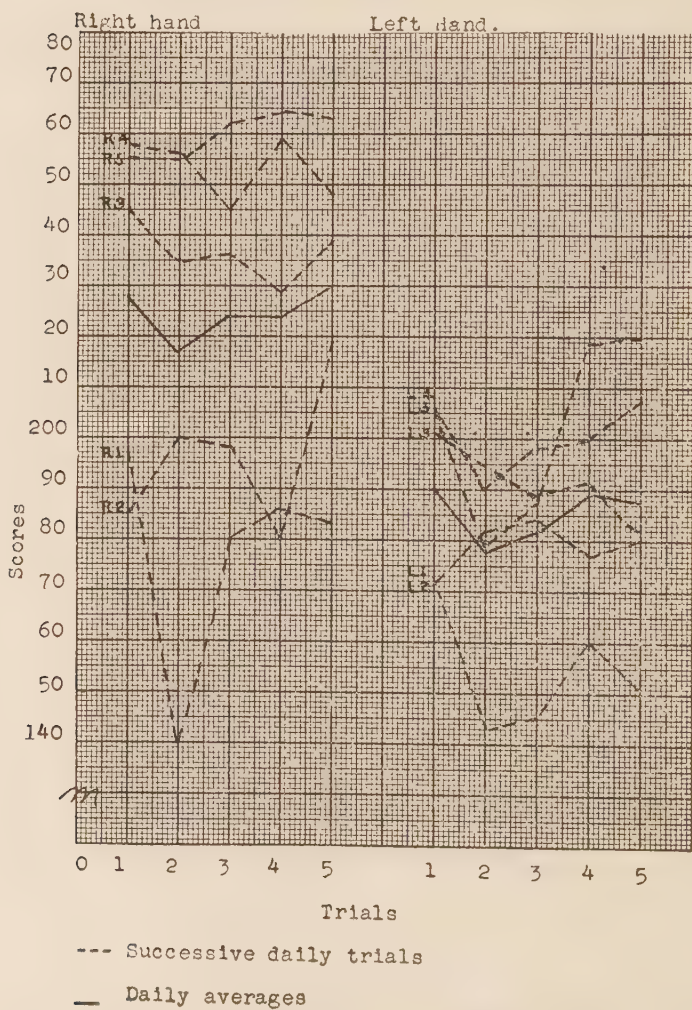


FIG. 22.—Subj. Hyd. Daily performance and general efficiency level.

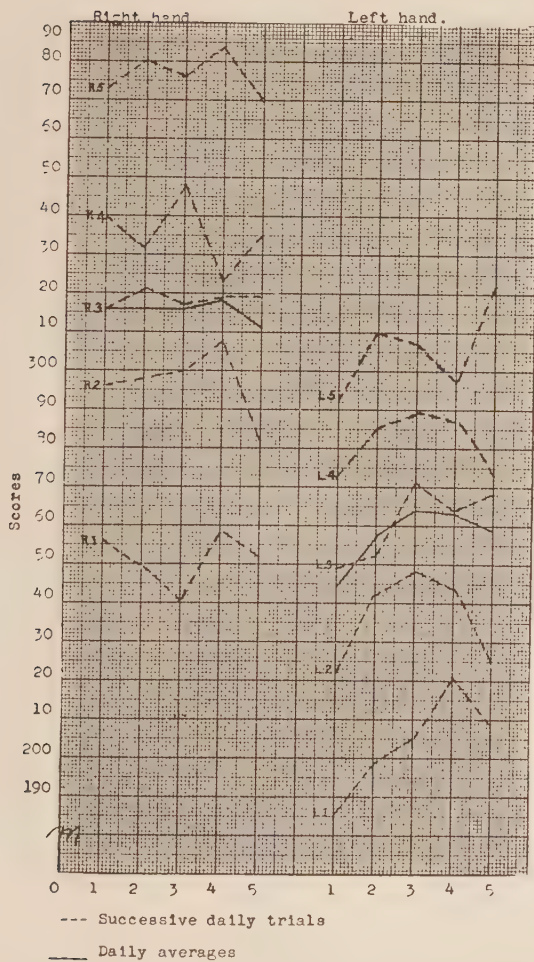


FIG. 23.—Subj. Llo. Daily performance and general efficiency level.

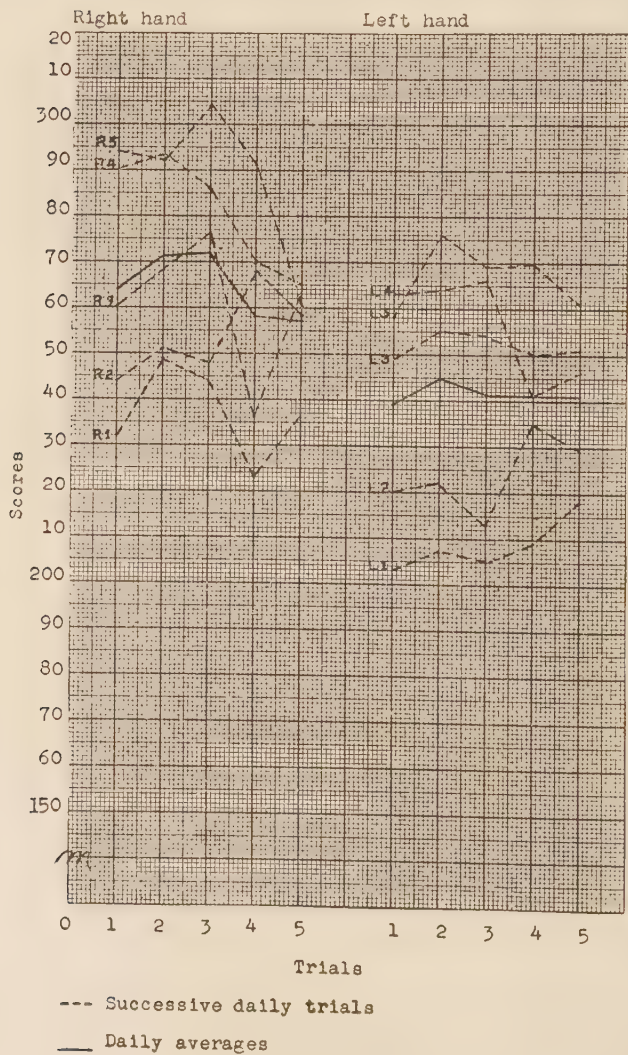


FIG. 24.—Sub., Pre. Daily performance and general efficiency level.

showing the second to second variation and decrease in speed, is necessary. The method used in this experiment gives an idea of only the gross fluctuations.

For computation of this index the formula of Gilbert (1892) was used. This is $f = \frac{r-s}{r}$. The number of taps in the first sixty second period are represented by r and the number in the last sixty by s . The measure of fatigue is the percentage of loss in rapidity during the last sixty seconds as compared with the first sixty seconds. All statements of group and individual differences are made on the basis of this f .

The results of the statistical analyses of the two groups are summarized and presented in Table VI. From this table it may be seen:

(1) That, as a group, the goiter group has a higher percentage of subjects showing immunity than fatigability. This is true for both hands and variations from the mean are small.

(2) Immunity to fatigue is considerably greater for the left hand than for the right.

(3) The non-goiter group shows slight susceptibility to fatigue with the right hand, but a marked immunity in the left, and slight variation from the mean in either hand.

(4) In both groups the plus and minus indices almost balance each other for the right hand, being practically equal in the goiter group.

(5) Compared in terms of variability and central tendency there are no significant group differences in fatigability.

An examination of the indices for all individuals of both groups showed no general regularity in the relative fatigability of the right and left hands among the different individuals; in some the right, in others the left hand

showed the greater immunity, and in the same individual sometimes it was the right, sometimes the left hand that showed fatigue.

TABLE VI.—STATISTICAL SUMMARY OF FATIGUE INDICES.
TAPPING TEST

	Goiter right	Non-goiter right
Number tested.....	103	51
Mean.....	-.0035 ± .0033	+.0037 ± .0053
Standard deviation.....	.0506 ± .0023	.0571 ± .0038
Difference in means.....	.0072 ± .0062	
D.....	1.1612	
P.E.D.....		
Difference in S.D.....	.0065 ± .0044	
D.....	1.4772	
P.E.D.....		
Mean plus scores.....	+.0356	+.0400
Mean minus scores.....	-.0420	-.0371
Percentage of plus scores.....	49.51 %	52.94 %
Percentage of minus scores.....	50.48 %	47.05 %
	Goiter left	Non-goiter left
Number tested.....	103	51
Mean.....	-.0201 ± .0030	-.0194 ± .0044
Standard deviation.....	.0454 ± .0021	.0468 ± .0031
Difference in means.....	.0007 ± .0053	
D.....	.1320	
P.E.D.....		
Difference in S.D.....	.0014 ± .0037	
D.....	.3783	
P.E.D.....		
Mean plus scores.....	+.0265	+.0267
Mean minus scores.....	-.0422	-.0446
Percentage of plus scores.....	32.03 %	35.29 %
Percentage of minus scores.....	67.96 %	64.70 %

In only 19.41 per cent of the subjects, in the goiter group, did the highest initial daily score correspond to the highest daily fatigue index for the right hand. In the left hand initial rate and fatigability were correlated in 30.09 per cent of the subjects. In the non-goiter group in 21.56 per cent of the subjects initial rate was correlated with fatigability in the right hand and in 27.45 per cent of the subjects in the left hand.

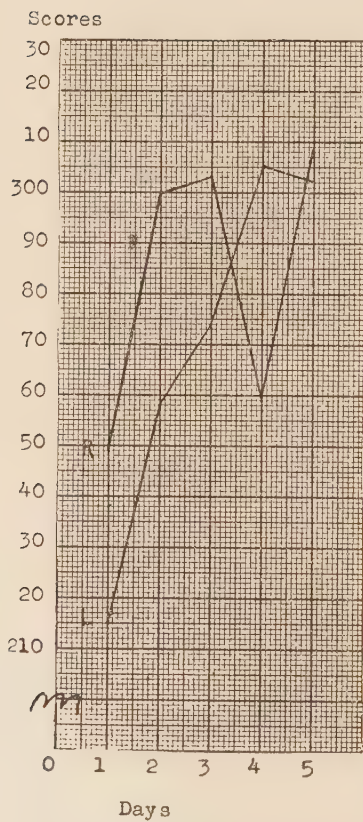
The lack of positive correlation between the hands, in both groups, may be interpreted to mean that in this

test, a general condition—general fatigability—is not tested in the groups as wholes by the method used here: rather the neuro-muscular mechanism involved in the movement of the two hands.

This interpretation seems further borne out by an inspection of specific indices, which shows that, with two exceptions, the subjects of the goiter group who exhibited tremor generally, or after tapping, also exhibited fatigability in the right hand but immunity in the left. This is likewise true of Wat, the only subject of either group who stopped tapping before the close of the experiment, because she was “too tired to tap any longer.”

Further evidence in favor of this interpretation is to be found in the practice curves of these subjects. These curves (figures 25–31) with one exception (figure 25) seem to indicate that these individuals have not reached the practice limit, but are still evidently in the early stages, as is shown by the very steep and continuous rise which indicates pure practice. The hands follow each other, the left always on a lower level of performance. For these seven subjects then it is reasonable to expect that fatigue has not taken place and each hand is subject to effects specific to itself. For Cun. and Llo. the practice curves are almost straight, ascending lines. The loss in efficiency in Ask. on the fourth day is the result of poor coördination and failure to tap with sufficient force to make the taps register.

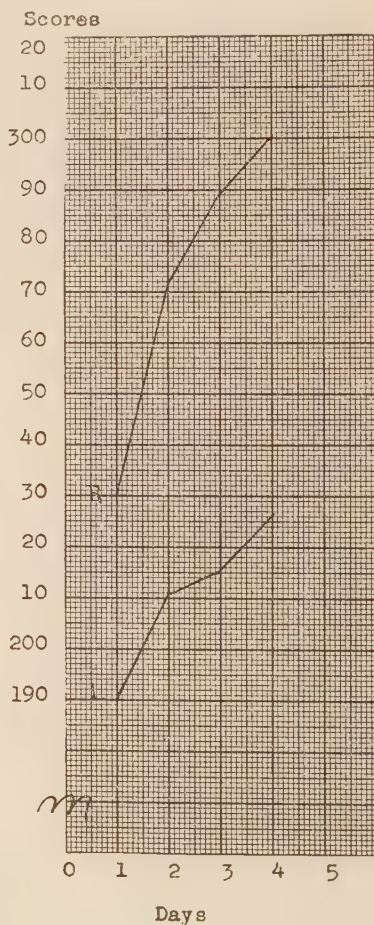
However, while this interpretation may hold for the subjects of the two groups, in general, and also for the goiterous subjects who exhibited tremor and a high pulse rate, still there are individuals within both groups for whom it does not hold, as is evident from a glance at figures 32–36. These curves show, in a gross way, the usual course of physical fatigue during practice, and the indices for both hands for the five subjects



R- Right hand

L- Left hand

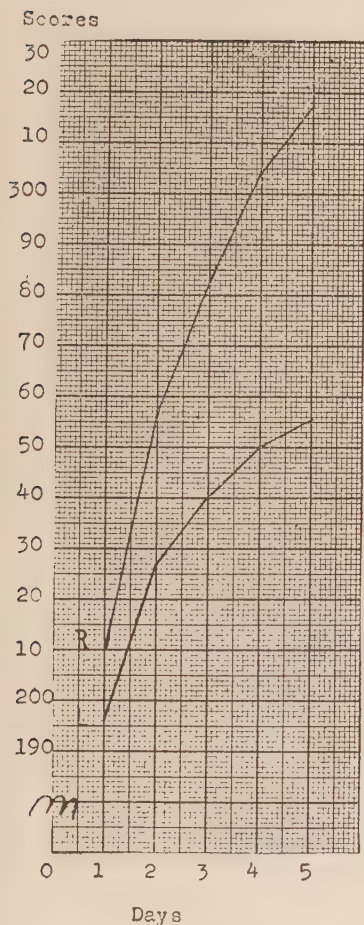
FIG. 25.—Sub., Ask. Practical curve.



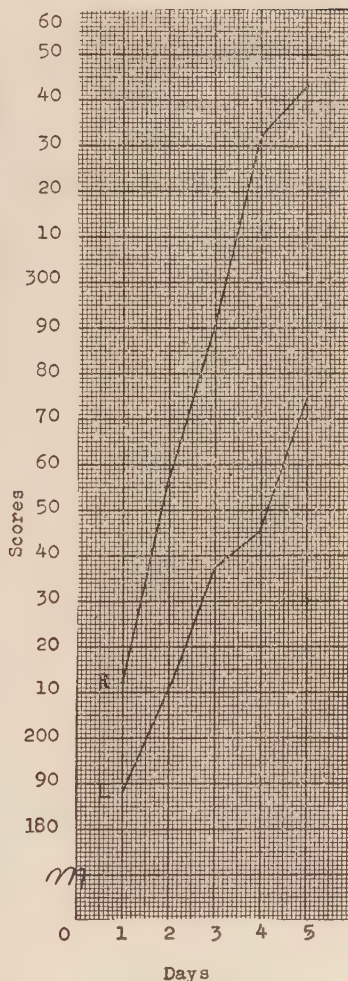
R- Right hand

L- Left hand

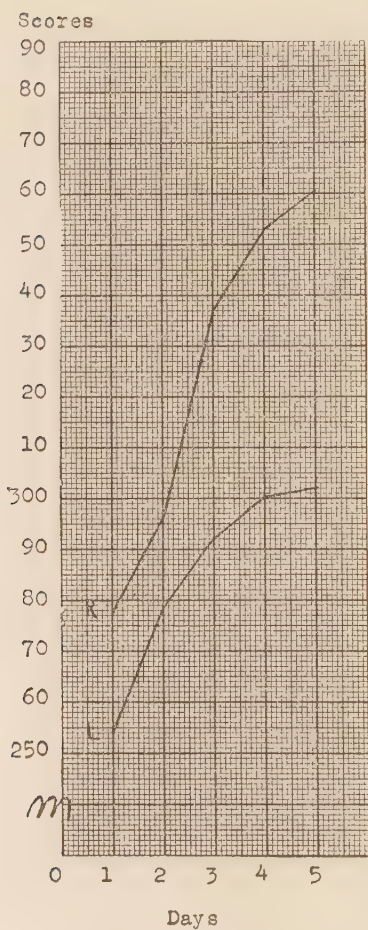
FIG. 26.—Sub., Coc. Practice curve.



R- Right hand
L- Left hand
FIG. 27.—Sub., Con. Practice curve.

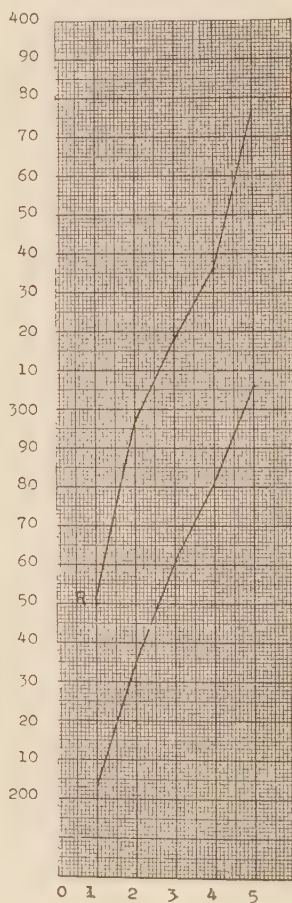


Days
R- Right hand
L- Left hand
FIG. 28.—Sub., Cun. Practice curve.



R- Right hand

L- Left hand



R-Right hand
L-Left hand

FIG. 29.—Sub., Hyd. Practice curve. FIG. 30.—Sub. L10. Practice curve.

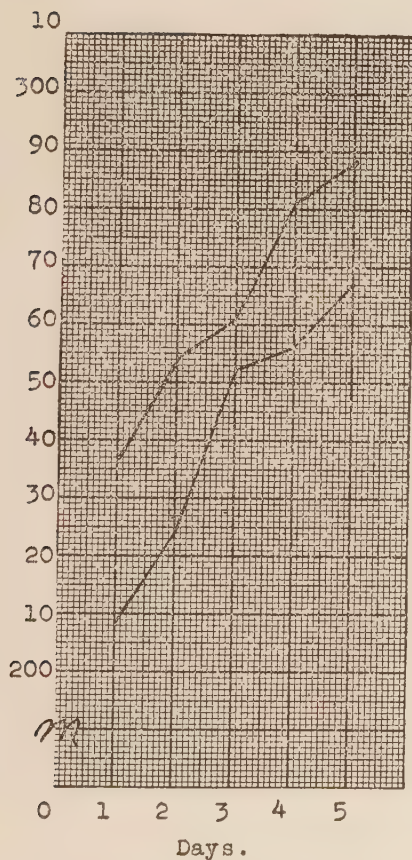


FIG. 31.—Sub., Pre. Practice curve.

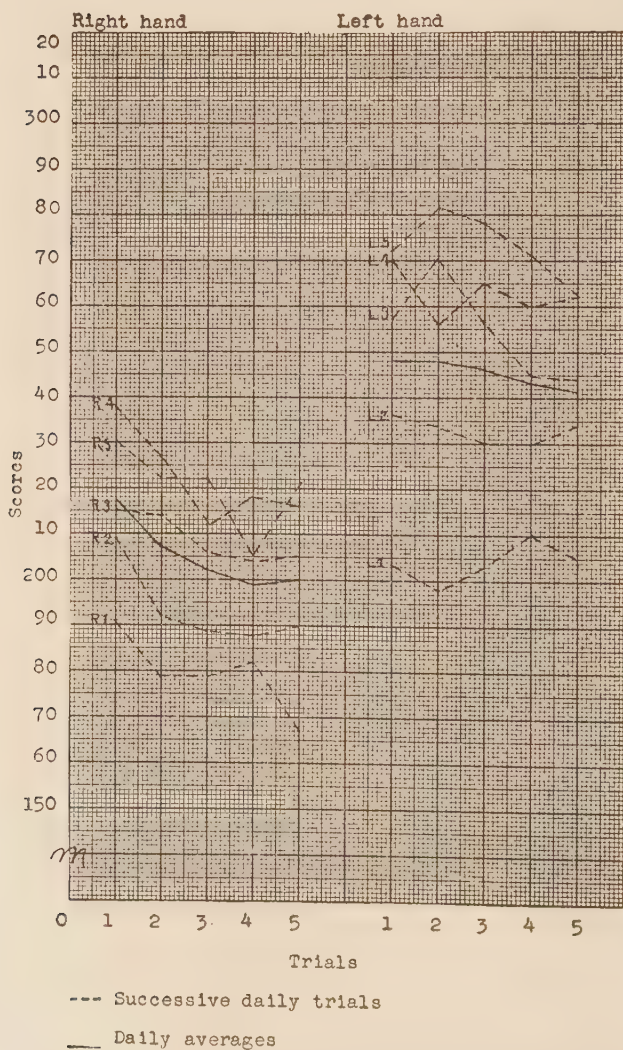


FIG. 32.—Sub., Alb. Daily performance and general efficiency level.

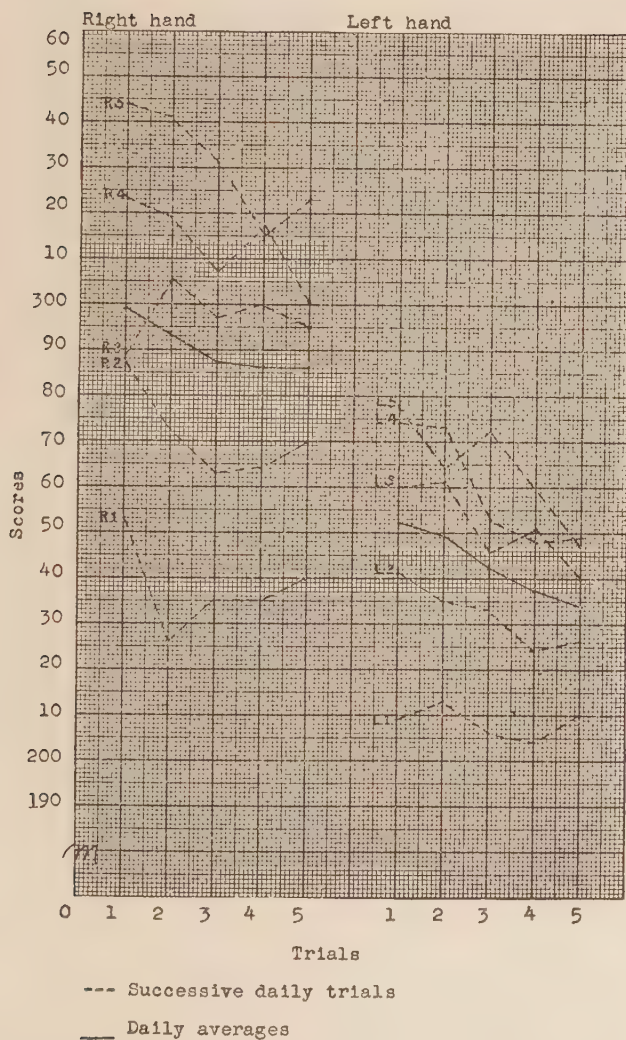


FIG. 33.—Subj., Dan-2. Daily performance and general efficiency level.

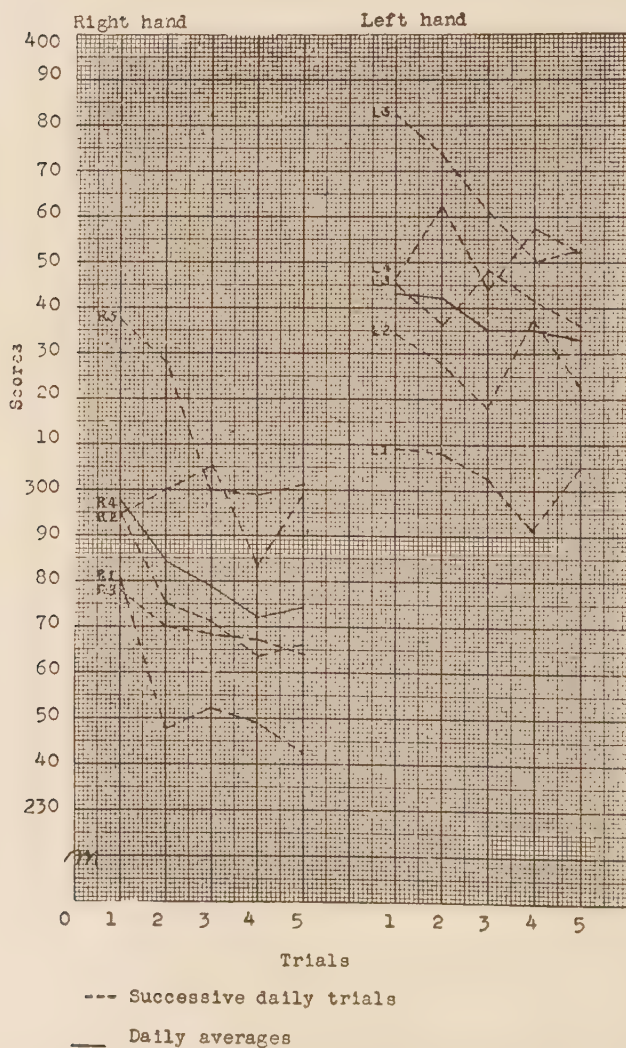


FIG. 34.—Sub., Dun. Daily performance and general efficiency level.

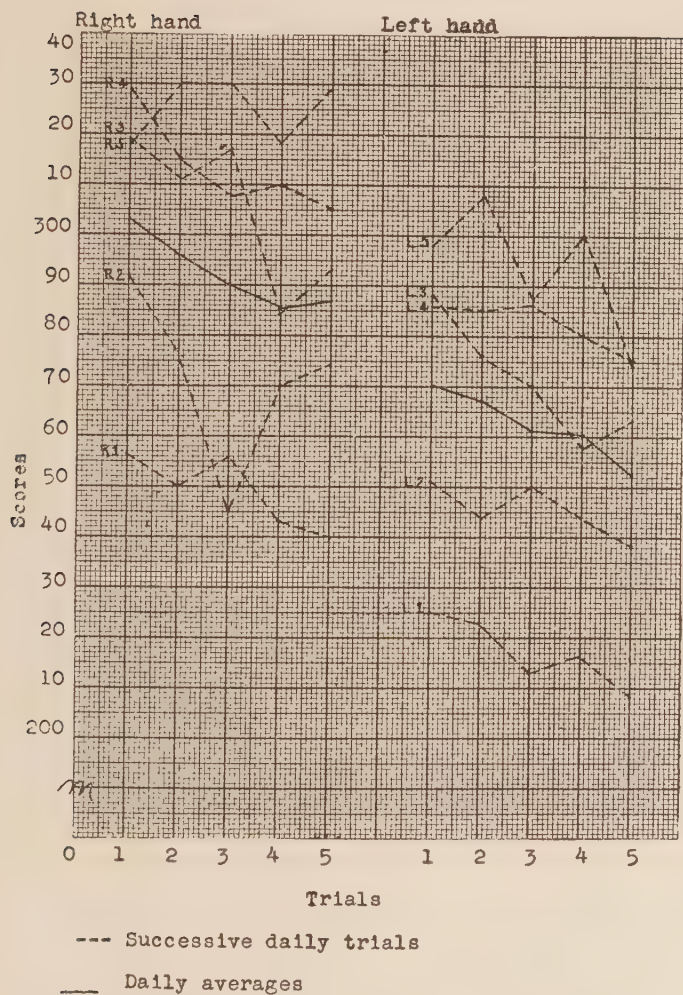


FIG. 35.—Sub., Hof. Daily performance and general efficiency level.

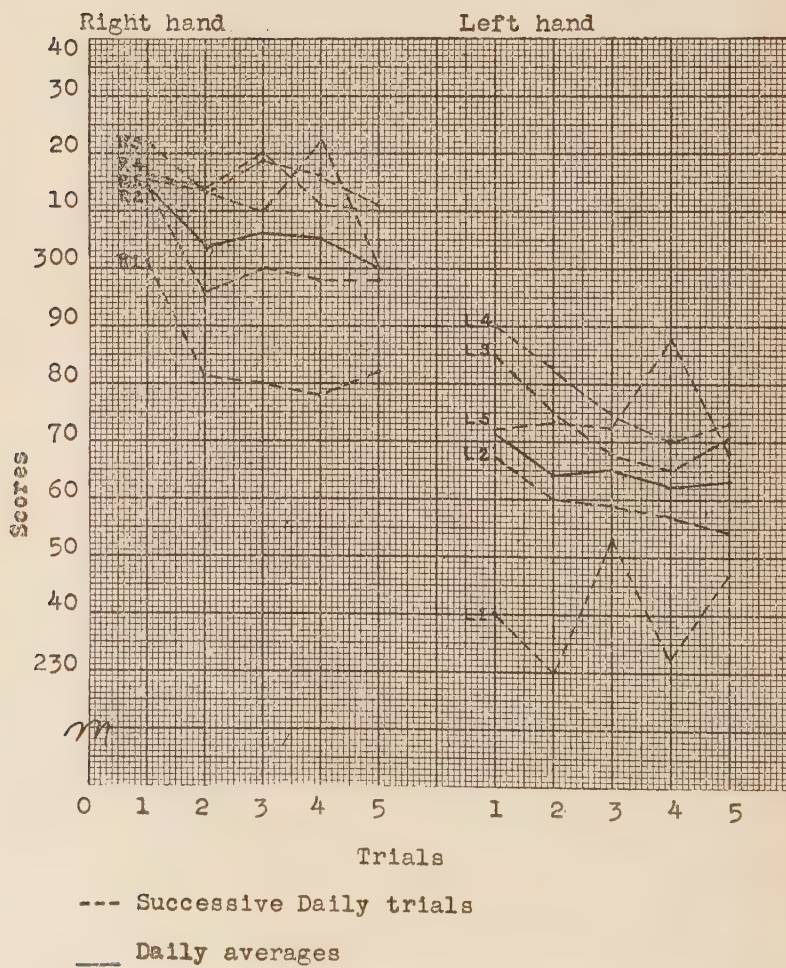


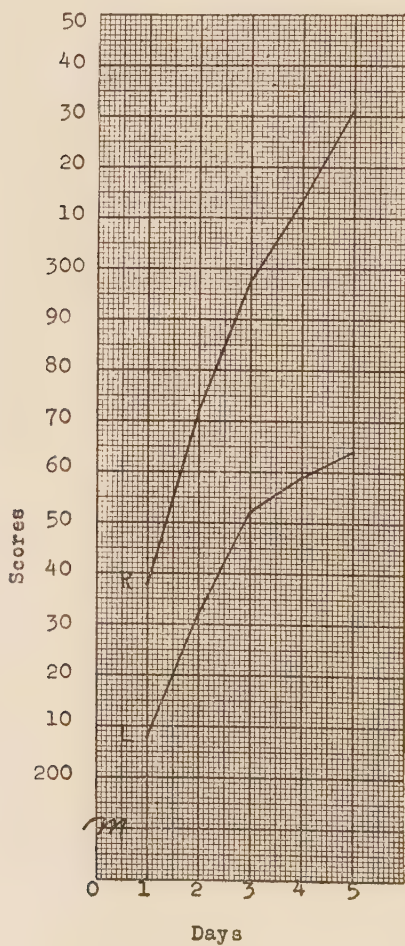
FIG. 36.—Sub., Sal-1. Daily performance and general efficiency level.

represented are consistently at the plus extreme. Further the weekly performance levels are consistently downward. And while the practice curves, plotted on the basis of the daily efficiency scores do not indicate that the limit of practice has been reached, nevertheless they do show a slight tendency to flatten.

In contrast to the daily performance curves for the subjects with high pulse rate and tremor, which are characterized by extreme variability, the curves for these subjects are characterized by a more or less gradual downward slope, or by a steep decline and then a more gradual falling off, variations which occur are comparatively slight; never extreme. The higher level of performance for the left hand of subjects Alb. and Dun. is due to the fact that they are left-handed. They show a superior performance for the left hand in all tests.

That fatigue occurred in these five subjects may be due to the fact that while tapping they maintained a more or less fixed bodily posture which contributed to uninterrupted tapping during each trial, while many of the other subjects, and especially the subjects who showed tremor, frequently stopped tapping for a fraction of a second to adjust the board, the cord, the stylus or herself. In these pauses two things took place; (1) recovery from fatigue and (2) a loss in practice. And according as the recovery or the loss was greater, the performance after the interval was better or worse.

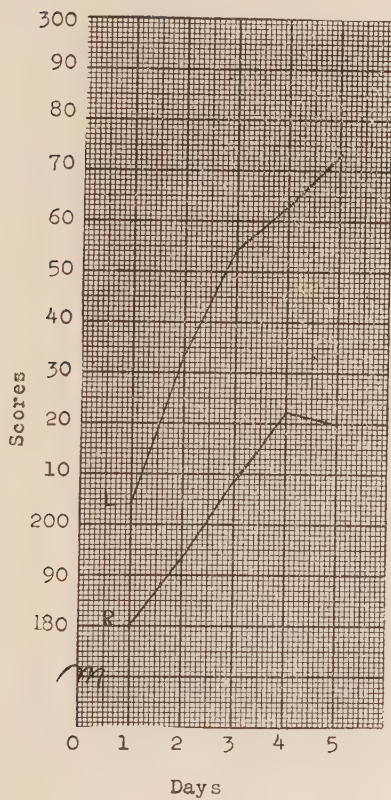
When the goiter group is reclassified according to diagnoses, no significant differences between groups are to be noted. The large enlargement group has a mean rate of 305.6 taps with a range of 252 to 341 for the right hand, while for the left hand the mean is 254.1 and the range 206 to 287. The means for the right and left hands of the medium group are 300.8 and 264.8 respectively. The ranges for these respective hands are



R- Right hand

L- Left hand

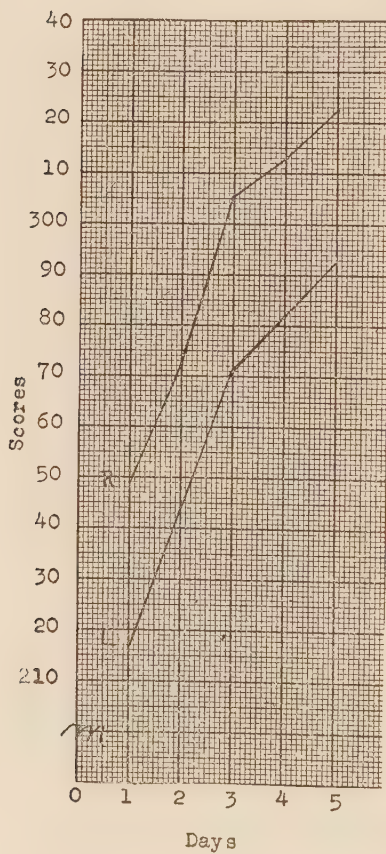
FIG. 37.—Sub., Alb. Practice curve.



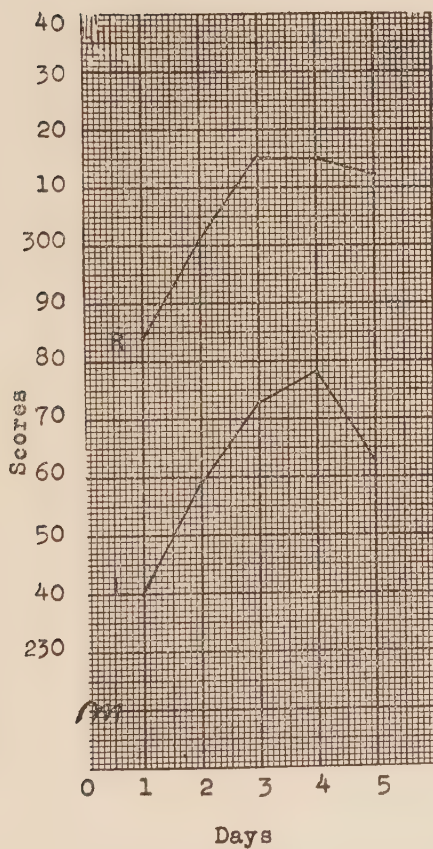
R- Right hand

L- Left hand

FIG. 38.—Sub., Dan-2. Practice curve.⁷



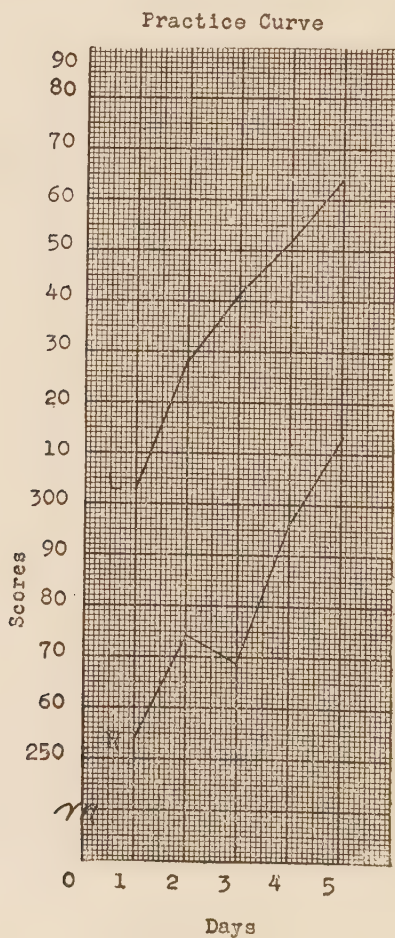
R- Right hand
L- Left hand
FIG. 39.—Sub., Hof. Practice curve.



R- Right hand

L- Left hand

FIG. 40.—Sub., Sal-1. Practice curve.



R- Right hand

L- Left hand

FIG. 41.—Sub., Dun.

256 to 345 and 229 to 328. For the small group the means for the right and left hands are 292.6 and 250.4, and the ranges are 225 to 345 for the right and 185 to 300 for the left hand. The adenomata group has a mean of 293.4 for the right hand and 261.5 for the left hand. The range for the former is 252 to 332; that for the latter is 210 to 338. Compared in terms of variability the medium group is the most variable group in the right hand and the adenomata group in the left hand.

Tables VII-VIIId and following curves give the statistical analyses of these sub-groups.

TABLE VII.—TAPPING TEST. LARGE THYROID ENLARGEMENT

Right hand							Left hand						
Average scores							Average scores						
Subject	Days						Days						
	1	2	3	4	5	Total	1	2	3	4	5	Total	
Boc.....	223	233	260	291	...	252	190	201	220	239	...	212	
Cro-3.....	278	290	307	321	338	307	229	239	258	282	285	259	
Dan-2.....	238	271	297	313	331	290	208	232	252	259	264	243	
Dic.....	310	335	...	318	344	328	260	287	...	298	303	287	
Flo.....	208	271	281	313	327	280	204	226	224	244	252	230	
Gat.....	280	306	316	314	...	304	251	282	242	251	...	257	
Hig.....	278	292	286	312	340	301	245	257	263	278	300	273	
Kel.....	306	310	341	356	...	328	265	269	292	313	...	285	
Lip.....	258	302	323	320	337	308	216	243	271	271	285	257	
Llo.....	251	297	318	336	377	316	204	236	261	281	306	258	
Mil-3.....	280	304	310	318	323	307	236	257	268	274	280	263	
Pha.....	274	317	320	320	...	308	236	237	273	276	...	256	
Poo.....	257	317	367	390	375	341	215	258	302	319	309	281	
Sho.....	276	294	302	294	...	289	187	199	216	222	...	206	
Sto.....	304	329	327	338	333	326	244	267	259	249	269	258	
Number tested.....							15						
Total score.....							4585.3						
Mean.....							305.6 ± 3.7491						
M.D.....							15.7						
S.D.....							21.5275 ± 2.6510						
Range.....							252-341						

TABLE VIIb.—TAPPING TEST. SLIGHT THYROID ENLARGEMENT

Right hand							Left hand						
Average scores							Average scores						
Subject	Days						Days						
	1	2	3	4	5	Total	1	2	3	4	5	Total	
And.....	253	312	316	320	328	306	211	246	273	300	283	262	
App.....	272	282	...	...	...	277	240	252	...	...	...	246	
Aye.....	232	315	...	322	324	311	236	265	...	271	285	264	
Ber.....	277	290	310	316	320	303	236	265	291	295	296	277	
Bla-1.....	267	289	296	320	...	293	229	333	254	264	...	270	
Bla-2.....	242	275	278	293	...	272	206	239	242	255	...	235	
Boo.....	242	281	307	307	289	285	197	218	231	223	229	219	
Bro.....	268	299	325	314	316	305	223	238	253	257	268	248	
Cha-2.....	275	284	302	313	317	298	239	242	259	280	292	262	
Clo.....	...	225	258	288	305	269	...	172	181	208	224	196	
Coo.....	296	306	285	245	308	288	244	251	221	228	286	246	
Cro-1.....	289	309	332	359	354	329	241	253	279	282	289	269	
Cro-2.....	337	334	328	324	350	334	252	257	261	290	308	274	
Cun.....	212	257	290	332	343	287	188	211	237	245	274	231	
Dav-2.....	261	292	318	343	...	303	201	237	256	365	...	265	
Edw.....	272	310	325	303	310	304	245	283	285	274	253	268	
Eic.....	232	269	262	283	312	272	206	229	215	235	247	226	
Fie.....	227	275	301	318	326	289	257	286	312	325	318	300	
Fre.....	321	350	343	354	357	345	248	290	277	296	311	284	
Gri-2.....	245	275	296	319	...	284	214	240	245	265	...	241	
Ham.....	258	272	278	312	326	289	222	238	266	280	298	261	
Har.....	244	297	313	324	344	304	202	236	271	279	287	255	
Hug.....	284	295	309	306	...	299	231	250	250	273	...	251	
Hyd.....	177	196	237	253	260	225	154	179	192	200	202	185	
Jen-1.....	276	284	303	315	314	298	222	233	243	259	254	243	
Klo.....	344	333	303	356	340	335	275	281	257	301	277	278	
Lew.....	263	286	297	307	311	293	211	215	231	235	245	227	
Mar.....	261	291	321	328	337	307	209	244	265	265	275	252	
Mil-1.....	241	259	275	291	...	267	216	232	239	251	...	235	
Plu.....	252	257	259	280	294	268	226	236	239	255	263	244	
Pre.....	237	254	261	281	288	264	208	224	252	256	267	241	
Ric.....	285	308	319	329	...	310	216	251	261	282	...	253	
Sal-1.....	284	301	315	315	312	306	240	259	273	278	275	265	
Sca.....	...	287	300	290	284	290	...	229	251	265	254	250	
Sip.....	221	234	252	265	270	249	200	203	218	220	226	213	
Wag.....	294	284	297	300	...	294	261	271	285	283	...	275	
Wal.....	243	261	275	288	...	267	192	212	213	228	...	211	
War.....	304	317	315	327	333	319	246	251	263	286	289	267	
Wat.....	250	283	297	294	...	281	263	281	316	334	...	274	
Wri.....	260	295	299	304	...	290	231	259	262	278	...	257	
Number tested.....													40
Total score.....													11707.2
Mean.....													292.6 ± 2.0702
M.D.....													17.4
S.D.....													19.4116 ± 1.4639
Range.....													225-345
Number tested.....													40
Total score.....													11707.2
Mean.....													250.4 ± 2.2790
M.D.....													18.5
S.D.....													21.3698 ± 1.6114
Range.....													185-300

TABLE VIIc.—TAPPING TEST. ADENOMATA

Right hand							Left hand						
Average scores							Average scores						
Subject	Days						Days						
	1	2	3	4	5	Total	1	2	3	4	5	Total	
Atk.....	248	264	278	240	302	266	216	237	245	232	281	243	
Bar.....	253	257	284	271	281	269	217	240	253	271	273	251	
Coc.....	230	272	288	300	...	273	190	211	215	226	...	210	
Die.....	292	333	326	323	320	319	248	282	285	265	260	268	
Dun.....	254	274	269	296	313	281	303	328	341	352	364	338	
Hin.....	236	249	271	...	...	252	206	226	249	...	...	227	
Hip.....	240	276	323	342	...	295	226	258	272	286	...	258	
Lag.....	210	275	308	312	313	284	204	234	250	254	265	241	
Lee.....	248	275	274	290	301	278	217	238	256	260	270	248	
Mas.....	230	269	282	290	303	275	205	236	238	254	261	239	
Mig-1.....	300	316	325	347	345	327	259	274	279	302	315	286	
Mig-2.....	298	304	336	349	353	328	254	267	299	310	320	290	
Nol.....	302	337	317	330	341	326	250	272	270	266	287	269	
Olm.....	311	333	342	346	326	332	241	282	289	292	306	282	
Ple.....	233	268	282	299	...	271	209	241	248	257	...	239	
Pri.....	274	301	301	316	319	302	228	241	242	268	270	250	
Rei.....	243	286	315	329	348	304	222	256	283	288	300	270	
Str.....	261	296	321	330	326	307	219	244	264	286	280	259	
Web.....	270	314	323	324	325	311	250	289	277	289	287	278	
Number tested.....	19						19						
Total score.....	5576.2						4969.8						
Mean.....	293.4 ± 3.7891						261.5 ± 4.4610						
M.D.....	22.6						22.3						
S.D.....	24.4873 ± 2.6793						28.8290 ± 3.1544						
Range.....	252-332						210-338						

TABLE VIIId.—DIFFERENCES IN CONSTANTS FOR GOITER SUB-GROUPS IN TAPPING TEST

Groups compared	Right hand			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	4.8 ± 5.3092	0.90	8.4870 ± 3.7542	2.26
Large-slight.....	13.0 ± 4.2827	3.04	2.1159 ± 3.0283	0.70
Large-adenoma.....	12.2 ± 5.3301	2.29	2.9598 ± 3.7691	0.79
Medium-slight.....	8.2 ± 4.2916	1.91	10.6029 ± 3.0346	3.49
Medium-adenoma.....	7.4 ± 5.3376	1.39	5.5272 ± 3.7742	1.46
Slight-adenoma.....	$.8 \pm 4.3178$	0.19	5.0757 ± 3.0531	0.66
	Left hand			
	Diff. in M.	$\frac{D.}{P.E.D.}$	Diff. in S.D.	$\frac{D.}{P.E.D.}$
Large-medium.....	10.9 ± 4.9267	2.21	5.4685 ± 3.4596	1.59
Large-slight.....	3.7 ± 4.3026	0.86	0.4143 ± 3.0424	0.14
Large-adenoma.....	7.4 ± 5.7636	1.28	7.8735 ± 4.0755	1.93
Medium-slight.....	14.4 ± 4.0183	3.58	5.0542 ± 2.8118	1.80
Medium-adenoma.....	3.3 ± 5.5546	0.59	2.4050 ± 3.9063	0.62
Slight-adenoma.....	11.1 ± 5.0094	2.22	7.4592 ± 3.5422	2.11

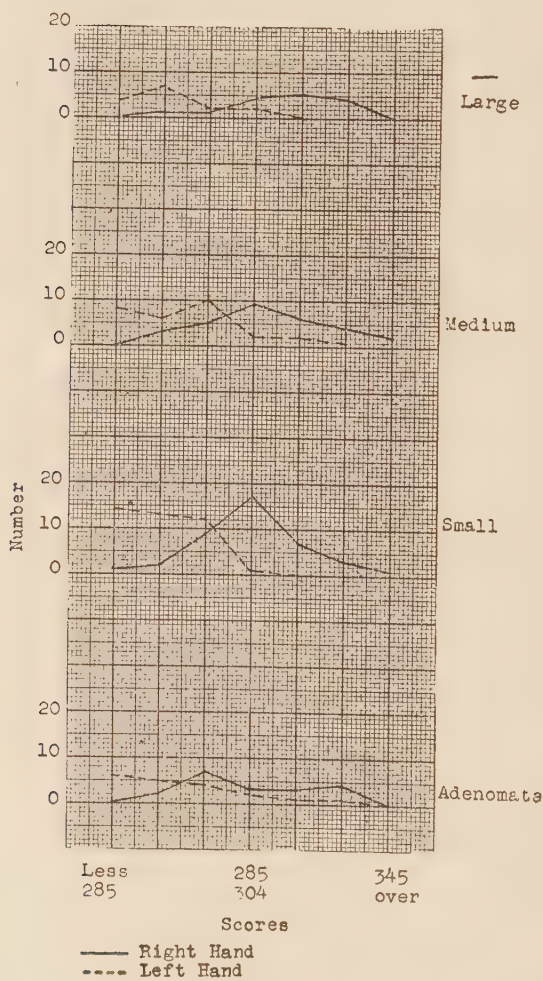


FIG. 42.—Distribution of scores. Goiter sub-groups. Tapping test.

4. SUMMARY AND CONCLUSIONS.

This section of the study contains a report on a team of motor-control tests given to a group of 103 goiterous adolescent girls and a group of 51 non-goiterous adolescent girls, ranging in age from 12 to 21 years of age. All of the subjects were examined by a physician. The diagnosis of thyroid enlargement was made by means of palpation and the enlargements classified according to size. Only a few of the thyroid group showed thyrotoxic symptoms. The findings may be summarized as follows:

1. In the ability to inhibit movement the two groups show no significant differences. On the contrary the goiter group with a mean of 63.3 contacts for the right hand, and a mean of 75.1 contacts for the left hand, in the steadiness test, stands only 1.1 and 1.2 points above the performance of the non-goiter group for the respective hands. The sigmas practically overlap and the reliability quotients are all less than 2.

2. The ability to coördinate eye and hand movements is on practically the same level in the two groups. In the J-D coördination form the goiter group made a mean time score of 98.3 seconds, the non-goiter group one of 98.6 seconds. The mean contact score for the former group is 5.2; that for the latter group 4.6 for five daily practice periods.

For the more difficult form—D form—the mean time score for the goiter group is 179.3 seconds and that for the non-goiter group 178.3 seconds. The contact scores for these respective groups are 55.5 and 56.7 respectively. The sigmas in both forms practically overlap and none of the reliability quotients exceed 2.

3. The dynamometer does not give measure of fatigue in this experiment. For the goiter group the average gross score, the average of the first and second trials,

and the average of the nineteenth and twentieth trials are 28.3, 28.2, and 28.9 respectively for the right hand. These respective averages for the same hand for the non-goiter groups are 29.5, 29.4, and 30.2. For the left hand of the goiter and non-goiter groups respectively they are 25.6, 25.9, and 25.9—and 26.7, 26.9 and 27.1.

The sigmas show no significant differences in variability and the reliability quotients range from less than 1 to 2 for the two forms.

4. For motor coördination and speed the two groups show the same type of performance for the left hand where the mean weekly score is 254.9 taps for the goiter group and 257.3 for the non-goiter group, the variability constant being for the latter group but one point above that for the former. For this hand the reliability quotients are less than one.

In the right hand the non-goiter group is the more variable. Here the average weekly score is 297.2 for the goiter group and 300.8 for the non-goiter group, with variability constants of 22.4 and 38.1 for the groups respectively and a sigma reliability quotient of 4.

5. The average of speed per second is strikingly low, being 2 taps per second lower than rates obtained by Gilbert, Dorcus and others. The maximum rate equals the average rate of these workers.

6. A general condition—fatigability—seems not to have been tested in either group, by the method used for tapping, excepting in a few cases.

7. In 19.41 per cent of the subjects of the goiter group in the tapping test, the initial daily score corresponds with the highest daily fatigue index for the right hand. This is true for 30.09 per cent of the subjects for the left hand. And for the non-goiter group it holds for 21.56 per cent of the cases for the right hand and for 27.45 per cent for the left hand.

The conclusions to be derived from the study are:

1. The groups studied are homogeneous.
2. Thyroid enlargement, in the majority of these subjects, appears to be a purely physiological state, either a compensatory adaptation of the organism, or a temporary enlargement. There are no significant differences in the constitution of the two groups, as groups.
3. Classification according to degree of enlargement of the thyroid gland does not furnish a basis for a measure of the functional activity of the gland and the degree of enlargement is not correlated with a like degree of incoördination and tremor.
4. Subjects with a high pulse rate, obvious tremor of the hands and tachycardia, even when the thyroid enlargement is very slight or imperceptible, show inefficiency in motor performance. Steadiness, coördination and speed of movement are decreased. These individuals fatigue readily and perspire profusely on continued exertion.
5. The motor tests used to detect incoördination of movement and tremor are well adapted for the purpose for which they have been used.
6. The methods used are not refined enough to give an accurate measure of the rate and amplitude of tremor or the course of fatigue.

AFTERWORD

Although but two of the goiterous subjects of this study present behavior difficulties serious enough to mitigate against efficient social, educational and industrial adaptation, and although but few exhibit inability to efficiently direct, inhibit or coördinate hand movements to a degree that would interfere with industrial placement nevertheless a practical word concerning the problem of thyrotoxicosis seems pertinent. The prob-

lem is a psychological one before it becomes a medical one. Normal and intelligent behavior which may be considered as a conscious and efficient adaptation to life situations is essentially a function of the central nervous system, which in turn appears to be more or less dependent upon a normal functioning of the thyroid gland. Thyroid toxin seems not only to endanger the vitality of the nerve elements, but also to raise or lower their threshold of excitability. The long continued influence of this toxin upon the nervous system results in a disturbance of function of the entire organism. "The mental, motor and trophic nerve centers lose their coördinative and sensitive power," the associative mechanisms do not function properly, and a long lasting influence of the toxin seems to result in impairment of the regulative and cortical system. An over active thyroid plus the toxins of the altered thyroxin molecule produce psychical disturbances, as well as motor ones. An extreme either way, lack or excess of thyroid function, causes depression or exaggeration of normal reactions respectively.

The individuals who exhibit tremor, high pulse rate (tachycardia) and vaso-motor disturbances in adolescence are often those who in later life find their way to the psychiatrist and physician because of mental and physical disturbances. En route they frequently pass under the observation of the psychologist to whom they should represent a problem of genuine scientific interest. These individuals are usually highly efficient persons in many respects but, only in certain environments and under certain conditions. Being possessed of a delicately adjusted nervous mechanism they do not function long, very efficiently, under long continued stress and strain. To begin with, being probably possessed of dominant thyroid function, they quickly pass, under adverse conditions, through numerous gradations

to a thyrotoxic state, which has its outward expression in restlessness, irritability, erratic behavior on formal occasions, suspicion, exaggerated emotional tonus, varying moods, and inability to attend to continuous mental work. To trivial annoyances they react with what Crotti calls a "thyrotoxic explosion."

But none seem to understand or to have studied the behavior patterns and reactions of these individuals sufficiently to be able to recognize the numerous gradations between the states representing normal function, thyroid balance or dominance, and those representing toxic states. The psychological picture in the varying states, is usually a mixed one and the psychologist who engages in describing the toxic subjects as psychopathic, psychoneurotic, queer and what not, without recognizing that these labels are mere blankets and that his concern is with the functional conditions differing from the average which underlie and partially condition or determine these terms, overlooks a profitable field of research. In applying the terms he has simply proved his linguistic skill in defining differences. However in resting the problem there he has ignored the dominating yet modifiable factors which have temporarily conditioned his terms.

The organic, physiological, and psychological correlates of these states should be investigated. These subjects should learn early the type of nervous mechanism that they possess. They should learn that many of their symptoms and reactions, such as suspicion, irritability, etc., have an organic basis and that they must learn how to react to it.

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